

APPENDIX D: Site Investigation Report



Report
Title:

Geo-Environmental Site Investigation

Project
Name:

Forest Farm, Chippenham



Report
Reference:

BRD2483-OR2-A

Date:

November 2023

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REPORT CONTROL SHEET

REPORT TITLE	GEO-ENVIRONMENTAL SITE INVESTIGATION
PROJECT	FOREST FARM, CHIPPENHAM
CLIENT	GLEESON LAND

REPORT REFERENCE	ISSUE DETAIL	DATE	PREPARED BY	CHECKED BY
BRD2483-OR2-A	Interim Issue – gas monitoring still ongoing.	30/11/2023	R Davies & A Leon	B Devonshire

BRD Environmental Limited

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- Ground Investigation
- Japanese Knotweed Removal
- Soil, Water and Gas Testing
- Contamination Assessment
- Geotechnical Advice
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Geo-Environmental Site Investigation
Forest Farm, Chippenham
BRD2483-OR2-A Chippenham SI

REPORT LAYOUT

This report is divided into the following four sections: Summary Report, Technical Report, Supporting Information and Appendices.

SUMMARY REPORT

This expanded executive summary provides the main findings of the work undertaken in brief non-technical language. This section provides an overview of the key outcomes for the benefit of non-specialists and concludes with the main recommendations. This section should only be relied upon in the context of the whole report and the Technical Report should be referred to with respect to any design decisions.

TECHNICAL REPORT

The main report section is intended to provide the technical detail of the investigation and is intended to provide the level of information required by current guidance documents and practice. The Technical Report is written in a language that, in part, assumes knowledge of subject matter so that it can be written in as concise a form as possible. Its intended audience is peers, regulators and other professionals in related disciplines.

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This section of the report provides background details of a generic nature together with specific technical approaches adopted by BRD and details of the guidance documents that are commonly referenced in the report. The section also includes explanations of technical terms to assist non-specialist readers in understanding the Technical Report. It should be noted that not all the information within this section is necessarily applicable to this specific report.		
APPENDICES		
The final section of the report presents the factual data collected and employed as part of the investigation.		
APPENDIX 1	SITE PLANS	
	Site Location Plan	Ref. BRD2483-OP1-B
	Revised Conceptual Site Model	Ref. BRD2483-OP7-A
	Proposed Development Layout	‘Illustrative Masterplan (DRAFT) – Land at Forest Farm, Chippenham’ Richards Urban Design, 1319.03, dated 06.04.22
	Exploratory Hole Location Plan	Ref. BRD2483-OD2-A
	Illustrative Ground Conditions Plan	Ref. BRD2483-OP8-A
APPENDIX 2	EXPLORATORY HOLE & MONITORING RECORDS	
	Logs of trial pits.	Ref. TP101-TP142
	Photographic records of trial pits.	Ref. BRD2483-OP6-A
	Logs of boreholes.	Ref. WS101-WS120
	BRE365 soakage test records.	4 x A4 pages
	Lightweight Deflectometer tests records.	Ref. LWD101-LWD104
	Gas monitoring records.	6 x A4 pages
	Groundwater monitoring records.	3 x A4 pages

APPENDIX 3 LABORATORY TEST RESULTS

DETS reports 23-13247.3, 23-13248.1 and 23-13517.1 33 x A4 pages

SPT report 43728_1 25 x A4 pages



SUMMARY REPORT - GENERAL INFORMATION

SUBJECT	COMMENTS
CURRENT SITE CONDITION	The site currently comprises agricultural fields used for cattle grazing and the production of hay or silage. Forest Farm and the immediate surrounding farmyard and grounds is located centrally in the southern half of the site but is excluded from the site boundary.
PROPOSED DEVELOPMENT	It is proposed that the site will be redeveloped as a residential housing estate with areas of public open space / amenity land. A new main road is proposed to the south of the farmyard and cuts through the site from a roundabout off the A4 to the east of the site. The land to the south of the new road is proposed to be retained as natural green space.
HISTORICAL SUMMARY	The site has generally remained undeveloped and in use for agricultural purposes throughout its history. The former Wilts & Berks Canal historically passed through the southern area of the site. The canal was abandoned in 1914 and infilled by the landowner in 1971.
PUBLISHED GEOLOGY	The site is shown to be devoid of superficial deposits. The majority of the site is indicated to be underlain by the Kellaways Formation and Oxford Clay Formation (undifferentiated). The southern area of the site is indicated to be underlain by the Kellaways Formation. Both formations are likely to be present as clay soils.
ACTUAL GROUND CONDITIONS	The investigation has proved a thin cover of Topsoil and Made Ground Topsoil overlying the Kellaways Sand Member present across most of the site typically in the topographically elevated areas, but also in the southern most part of the site which in turn overlies the Kellaways Clay Member. The Kellaways Clay Member is present underlying the Topsoil and Made Ground Topsoil in the areas of the site where the Kellaways Sand Member is absent. The Oxford Clay Formation, shown to be in the published geology maps, was not encountered during the investigation.
HYDROGEOLOGY	The bedrock geology, the Kellaways Formation and Oxford Clay Formation (undifferentiated) and the Kellaways Formation, shown underlying the site are designated Unproductive Strata. The Kellaways Sand Member shown in the surrounding area is designated a Secondary A Aquifer. The site is not located within a groundwater Source Protection Zone.
HYDROLOGY	The closest water feature to the site is a ditch which flows through the southern half of the site in an east to south west direction. The site is not in an area indicated to be at risk of flooding.
PREVIOUS GROUND REPORTS	There is physical evidence of a previous ground investigation but the associated investigation report has not been provided to BRD. However, BRD has undertaken geo-environmental desk study research and this has been reported separately.

SUMMARY REPORT - GEOTECHNICAL

SUBJECT	COMMENTS
EXCAVATIONS	It should be possible to forward excavations employing normal equipment. The use of hydraulic breaking equipment will be required for forwarding some excavations at the site. Limited groundwater control in the form of pumping from sumps is likely to be required but specialist groundwater control, such as well pointing, will likely need to be considered in some areas.
SLOPE STABILITY	Moderate slope have been recorded across most of the site and any change in levels required by the development should be cut to a shallow slope or should be supported by appropriately designed and constructed retaining walls.
SUB-SURFACE CONCRETE	<u>Kellaways Sand Member</u>: Design Sulphate Class of DS-1 and Aggressive Chemical Environment for Concrete class of AC-1 applies. <u>Kellaways Clay Member</u>: Design Sulphate Class of DS-4 and Aggressive Chemical Environment for Concrete class of AC-5 applies.
SOAKAWAYS	Site is not suitable for surface water disposal to soakaways or other forms of infiltration device.
PAVEMENT DESIGN	<u>Deep Made Ground</u>: A preliminary design California Bearing Ratio (CBR) of less than 2% and geo-grid reinforcement has been recommended. <u>Site-wide</u>: A preliminary design CBR of 3% has been recommended.
FOUNDATIONS	
LIKELY FOUNDATION TYPE	Shallow strip or deeper trench fill footings bearing upon the Kellaways Sand or Clay Member. Due to the likely variability of the soils at founding level, light steel mesh reinforcement will generally be required. Piled foundations may be required within influence of existing trees.
VOLUME CHANGE POTENTIAL	Medium i.e. moderate swelling or shrinking with moisture content changes.
ESTIMATED FOUNDATION DEPTHS	The minimum footing depth required is 0.90m, but 1.25m where required to allow for restricted new tree planting. Pile lengths to be determined by specialist piling contractor.
HEAVE PROTECTION	Will be required for those plots located in close proximity to the boundary fields trees.

SUMMARY REPORT - CONTAMINATION ISSUES

SUBJECT	COMMENTS
SOIL RISKS TO HUMAN HEALTH	No unacceptable contamination in respect of human health have been identified by this investigation.
LANDFILL GAS	The initial gas monitoring would suggest that some form of gas protection measures will be required in the southern area of the site where the infilled canal is present, but unlikely to be needed elsewhere. However, a full characterisation of the gas regime at the site is not possible at this stage due to shallow groundwater. The gas monitoring programme is ongoing and this risk assessment will be updated on completion of that.
RADON GAS	Radon gas protection measures are not required.
RISKS TO THE WATER ENVIRONMENT	No unacceptable contamination risks to water resources have been identified by this investigation.
RISKS TO BUILDING MATERIALS AND SERVICES	No unacceptable contamination risks to building materials and services have been identified by this investigation.
REMEDIATION	The need for any remediation will be dependent on the findings of the additional investigation recommended, in particular the gas monitoring.
ASBESTOS	No asbestos has been detected in the soil samples tested. No suspected asbestos containing materials has been observed in the soils inspected.
WASTE SOIL DISPOSAL	The topsoil is unlikely to constitute 'inert waste' due to its high organic matter content. It is considered that the Made Ground soils from the infilled former canal disposed of from the site would be classified as 'non-hazardous waste'. It is considered that the natural sub-soils disposed of from the site would be classified as 'non-hazardous waste' and would likely be characterised for disposal to landfill as 'inert waste'.

SUMMARY REPORT - KEY RECOMMENDATIONS

RECOMMENDATIONS

Geotechnical

The boundaries between the Kellaways Sand and the Kellaways Clay Members have been only approximately delineated. Once the final layout is completed further a more detailed investigation should be considered in order to increase exploratory points density and to provide a better delineation of the contact between both strata.

Further ground investigation by a senior experienced geologist should be undertaken to determine the extent, nature and significance of potential superficial deposits that may include landslide derived material.

Once development levels are determined further investigation in areas of significant cut will be required for earthworks design.

Where piling is the foundation solution further deep borehole ground investigation will be required for design.

Contamination

In line with the guidance in CIRIA C665 it is considered that at least 6No. further monitoring visits will be required to fully evaluate the gas regime. It would be preferable to undertake the additional monitoring when the groundwater levels have subsided after a period of drier weather. Consideration should also be given to raising monitoring wells to be above ground. On completion of these visits, the gas risk assessment will be updated.

If the 30m exclusion zone around the active transmission pipeline can be significantly reduced, it is considered that further exploratory points in the vicinity of the underground fuel pipelines and the infilled former pond would be prudent.

1. INTRODUCTION TO TECHNICAL REPORT

1.1. CONTRACT DETAILS

CLIENT	Gleeson Strategic Land Ltd trading as Gleeson Land.
SITE	Land situated at Forest Farm in the town of Chippenham, Wiltshire.
CLIENT'S ADVISORS	BRD Environmental Limited (BRD) has been commissioned directly by the Client.
REPORT CONTEXT	It is understood that the Client intends to market the site for residential redevelopment.
REPORT TYPE	Geo-environmental site investigation (i.e. combined geotechnical ground investigation and Phase 2 contamination assessment).
REPORT OBJECTIVES	The site has been the subject of a desk study referenced as follows: • 'Phase 1 Geo-Environmental Desk Study – Forest Farm, Chippenham', BRD Environmental Ltd, report ref. BRD2483-OR1-B, dated November 2023. The purpose of the report is to present the findings of a ground investigation, and to present both geotechnical and contamination assessments of the ground conditions revealed.

1.2. SCOPE OF WORKS

The agreed scope of works was:

- Mobilisation to site and production of health and safety documentation.
- Four days of windowless sampling using a percussive drilling rig to provide approximately 20No. boreholes to a nominal depth of 3m-5m, ground conditions permitting. Undertake Standard Penetration Tests (SPT) at 1m intervals. Installation of a 4m depth combined gas and groundwater monitoring well (nominal 50mm diameter) into 14No. boreholes. Installations will be finished with a flush fitting metal stopcock cover.
- Five days of trial pitting using a mechanical excavator to provide approximately 40No. trial pits to a nominal depth of 3m, ground conditions permitting.
- Performance of soakage tests based upon BRE Digest 365 within 4No. of the trial pit locations. Supply of water to site via a 4WD water bowser unit on one day for the filling of each test pit. A Geo-Environmental Technician will monitor the soakage tests. As the pits are expected to fail we are not envisaging the need for any return visits.
- Undertake 4No. in-situ Lightweight Deflectometer (LWD) plate tests along the line of the proposed road at a depth of around 0.5m bgl, ground conditions permitting, to determine equivalent CBR values.
- All exploratory points will be logged and sampled in general accordance with BS5930:2015 by supervising Geo-Environmental Consultant.
- In-situ geotechnical testing of fine soils using a Hand Shear Vane and/or Pocket Penetrometer.

- Determination of the accurate location and level of exploratory points by topographical GPS unit.
- Geo-Environmental Technician to undertake a total of 9No. combined gas, vapour and groundwater monitoring visits. For gas, the determination of oxygen, carbon dioxide, methane, hydrogen sulphide and carbon monoxide concentrations, together with atmospheric pressure and flow rates, using portable equipment. For vapours, determination of the concentration of volatile organic compounds by photo ionisation detector. For groundwater, the determination of groundwater levels.
- Chemical testing of soil samples to confirm the soils are uncontaminated, to determine waste classification for muckaway and to meet the requirements for new water supply pipe specification. Budget based on the following testing schedule:
 - o 25No. Metals Suite - As, Cd, Cr, CrVI, Hg, Pb, Se, Cu, Ni and Zn.
 - o 25No. Inorganics Suite - water soluble sulphate, pH, organic matter.
 - o 25No. Speciated Polycyclic Aromatic Hydrocarbons (PAH).
 - o 10No. Banded aliphatic/aromatic Total Petroleum Hydrocarbons (TPH).
 - o 10No. Benzene, Toluene, Ethylbenzene, Xylene (BTEX) and Methyl Tertiary Butyl Ether (MTBE) compounds.
 - o 4No. Semi-Volatile Organic Compounds (SVOC) suite.
 - o 4No. Asbestos quantification.
 - o 10No. Organochlorine Pesticides suite.
- Geotechnical testing as appropriate to the nature of the ground conditions encountered, but the budget is based on the following testing schedule:
 - o 16No. Moisture content.
 - o 16No. Plasticity indices.
 - o 4No. Particle size distribution by wet sieve with 2No. by follow on hydrometer.
 - o 12No. pH and water soluble sulphate analysis - soil.
 - o 12No. Total sulphate and sulphur analysis - soil.
 - o 4No. pH and sulphate analysis - water.
- Provision of a combined factual and interpretative investigation report. Factual findings to include all exploratory point records, monitoring and test results. Interpretative reporting to include a summary of information from desk study research, a Generic Quantitative Contamination Risk Assessment (GQRA), waste classification and a Geotechnical Assessment providing comments on pavement design, concrete classification, soakaway feasibility, foundation design recommendations. Report to be supplied in an electronic Adobe pdf format.

1.3. REPORT LIMITATIONS

Any site boundary lines depicted on plans included within this report are approximate only and do not imply legal ownership of land. Any observations of tree species, asbestos containing materials within structures or invasive weeds, does not constitute a formal survey of such features. The identification of such features is therefore tentative only. In the case of Japanese Knotweed, BRD can undertake separate surveys for this plant undertaken by a Property Care Association qualified surveyor.

The report does not consider whether sensitive ecology or archaeology is present as these require consideration by professionals specialising in these matters. It should be recognised that the collection of desk study information may not be exhaustive and that other information pertinent to the site may be available.

The recommendations, interpretations and conclusions of this report are based solely on the ground conditions found at the exploratory holes. Due to the variability in the nature of ground, conditions between exploratory holes can only be interpreted and not defined. The description of the site and the ground conditions is accurate only for the dates of the field works. In particular, groundwater levels can vary due to seasonal and other effects.

The assessment and interpretation of contamination risks is based on the scope of works agreed with the Client together with the budgetary and programme constraints imposed. Further investigation, analysis and assessment of contamination may be required by regulators or other third parties with an interest in the site. An ecological risk assessment of contaminated soils is beyond the scope of this report. This report is concerned with assessing those contamination risks which apply to the future use of the site through the proposed development as part of the planning regime. The assessment does not consider the risk to current site users or continued future use of the site in its current state. If development of the site should occur that differs from that proposed, then the findings of the contamination assessment would need to be re-evaluated.

At the time of writing, detailed information on the proposed structure, such as detailed layout, loadings and serviceability limits, was not available. Accordingly, where geotechnical design advice is provided it is on the prescriptive basis allowed for by Eurocode 7: employing conventional and conservative design rules. The scope of this investigation excludes a formal slope stability study and any observations made regarding slopes are for information only.

2. SITE CHARACTERISTICS

2.1. SITE SETTING

SITE ADDRESS AND POST CODE	Land at Forest Farm, Pewsham, Chippenham, Wiltshire, SN15 3RP.
NATIONAL GRID REFERENCE	The site is approximately centred on 393950E, 171630N.

2.2. SITE DESCRIPTION

SUBJECT	COMMENTS
CURRENT SITE DESCRIPTION	The site currently consists of agricultural fields used for cattle grazing and the production of hay or silage. Within the site, Forest Farm farmyard and grounds are located centrally in the southern half, but this area is excluded from the proposed application boundary. Forest Farm is a small dairy farm with associated barns, storage areas and slurry pit, as well as the main farmhouse and a separate bungalow named 'Trevan'. The site covers an area of approximately 39 hectares and is irregularly shaped. Vehicular access to the site is from the access track down to Forest Farm off the London Road (A4), which is located along the northern boundary of the site. Pedestrian access is also possible from the western and southern boundaries along the route of a public footpath. The boundaries of the site are predominantly defined by dilapidated wooden post and rail or post and wire fencing that is generally contained within mixed hedgerows including mature trees. The topography of the site generally slopes from north west to south east up to the ditch that runs east to south west in the southern half of the site. The overall drop in levels across the site is from 66m Above Ordnance Datum (AOD) in the north corner to 52mAOD in the south western corner. To the south east of the ditch levels start to gently rise towards the south eastern corner with levels rising to between approximately 53mAOD and 57mAOD, creating a shallow valley feature present either side of the ditch. There are no buildings are present on site. The access track is surfaced with poor quality tarmac and tarmac fragments that have been patch repaired in numerous places. The remainder of the site comprises grass covered fields. The boundaries of the site and the field boundaries are mixed hedgerows containing predominantly hawthorn. Numerous mature trees including oak and sycamore were identified along the boundaries. Willows and a leylandii were also noted in the south western corner of the site adjacent to the ditch. A single mature oak tree is present in the middle of the field in the north western area of the site. A number of overhead electricity transmission lines are present on the site. Crossing north to south through the western half of the site are high voltage cables on large metal pylons. Crossing from east to west through the northern centre of the site are more electricity cables located on tall

SUBJECT	COMMENTS
	wooden poles. In addition, some of the poles were noted to have above ground transformers, implying some underground cable feeds are also likely to be present. A live underground fuel pipeline is known to run across the north eastern section of the site. Marker posts are evident in the boundary hedgerows, confirming the pipe's location. A live foul rising sewer runs approximately parallel to the north eastern boundary of the site, but its exact location is unknown. A modern plastic double bundled above ground oil tank was observed adjacent to the off-site bungalow, 'Trevan', within the farmyard area. A modern bundled fuel tank was also observed within the farmyard area. To the south east of the farm yard is a slurry pond and associated infrastructure. Discussions with the farmer confirmed that a network of underground pipes is present in the south eastern field which enables water from the slurry pond to be pumped on to this area.
SURROUNDING LAND USE	The site is set on the eastern fringes of the district of Pewsham in Chippenham within a mixed residential and agricultural area. The site surrounds Forest Farm which is located centrally in the southern half of the site. London Road (A4) is present abutting the majority of the north eastern boundary. To the northernmost tip of the site are some residential dwellings and another farmhouse. Residential development is also present further to the north west. To the east there are predominantly agricultural fields, with some limited residential development, small commercial or light industrial areas and farms. Approximately 100m to the east of the site is a Hyundai vehicle garage. To the south there are predominantly agricultural fields, with farmyards and associated buildings. To the immediate south west is an area of woodland, which is known to be a former brickworks. The area is at a lower elevation to the site but can be accessed via steep sided banks covered by mature trees. These open excavations are present at depths ranging from approximately 2m to 4m bgl below the adjacent site levels. The ponding of water the was observed at the base. Pewsham Way is present to the west, with residential development beyond.
PROPOSED DEVELOPMENT	The proposed end use of the site is for the development of a residential housing estate with large areas of public open space / amenity land. A new main road is proposed to the south of the existing farmyard and cuts through the site from a roundabout off the A4 to the east of the site. The land to the south of this new road is proposed to be retained as natural green space.

SUBJECT	COMMENTS
HISTORICAL SUMMARY	From the previous desk study report, the following summary of the site's history is presented. The site has generally remained undeveloped and in use for agricultural purposes throughout its history. The former Wilts & Berks Canal historically passed through the southern area of the site. The canal was abandoned in 1914 and infilled by the landowner in 1971.
PUBLISHED GEOLOGY	The site is shown to be devoid of superficial deposits. The majority of the site is indicated to be underlain by the Kellaways Formation and Oxford Clay Formation (undifferentiated). The southern area of the site is indicated to be underlain by the Kellaways Formation. Both formations are likely to be present as clay soils.
RADON	Radon protection measures are not required.
HYDROGEOLOGY	The bedrock geology, the Kellaways Formation and Oxford Clay Formation (undifferentiated) and the Kellaways Formation, shown underlying the site are designated Unproductive Strata. The Kellaways Sand Member shown in the surrounding area is designated a Secondary A Aquifer. The site is not located within a groundwater Source Protection Zone.
HYDROLOGY	The closest water feature to the site is a ditch which flows through the southern half of the site in an east to south west direction. The site is not in an area indicated to be at risk of flooding.

2.3. PREVIOUS INVESTIGATIONS

As discussed in the desk study report, three raised borehole monitoring installations present in the southern area of the site, indicating that some ground investigations works had been completed by others. However, the associated investigation report has not been provided to BRD.

Aerial images indicate that a detailed archaeological investigation has been completed incorporating a network of trenches across the southern half of the site. The associated report has also not been provided to BRD.

The site has been the subject of geo-environmental desk study research by BRD and this has been reported separately in 'Phase 1 Geo-Environmental Desk Study – Forest Farm, Chippenham', BRD Environmental Ltd, ref. BRD2483-OR1-B, dated November 2023. This current report should be read in conjunction with the previous desk study report.

2.4. FUEL PIPELINES

Three underground fuel pipelines are known to present in the northern half of the site, with one active and two redundant. The live pipeline is managed by Exolum and the redundant pipelines by Defence Infrastructure Organisation (DIO). All the pipelines are located along a similar corridor on site, whereby the pipelines cross between the eastern boundary and the north western boundary. The location of the active pipeline is identified by yellow aerial pipeline marker posts which are present in the hedgerows.

As part of the walkover for the desk study report, BRD met with a representative from Exolum on site and confirmed the location of the pipelines crossing the site. The active pipeline is present at depths of approximately 0.8m to 1.0m bgl. One redundant pipeline is located along a similar line to the active pipeline and one is approximately 5m to the north. Both of the redundant pipelines are present at depths ranging from approximately 0.6m to 0.8m bgl.

During the meeting, a 30m offset was agreed with Exolum for any future ground investigation works. Limitations were also placed on plant / machinery crossing the pipeline and it was agreed that all crossings would take place on the existing access track. This negated the use of temporary ground protection mats at all crossing points.

3. GROUND INVESTIGATION

3.1. INVESTIGATION DESIGN

METHODOLOGY	Trial pits were selected as they expose more soils which enables a more reliable record of the ground conditions encountered and allow for BRE365 soakage tests and CBR tests to be undertaken. Windowless sample boreholes were selected as monitoring installations were required and in-situ density tests were required in the coarse soils. Gas and groundwater monitoring was selected in order to assess the risk from landfill gasses and to record seasonal variation in resting groundwater levels.	
DATES OF SITE WORKS	The main field works were undertaken on 16th to 20th October 2023. Monitoring visits were undertaken on 24th, 30th October, 7th November 2023. A further 3No. gas monitoring visits are proposed at the site.	
CONSTRAINTS TO EXPLORATORY HOLE LAYOUT	No exploratory holes were undertaken within close proximity to any of the services present on the site.	
EXPLORATORY HOLE SPACING	Approximately 50m to 100m grid.	
LAYOUT RATIONALE	SOURCE / FEATURE	EXPLORATORY HOLE
CONTAMINATION SOURCES TARGETED	On site infilled former canal.	TP121, TP122, TP124, TP125, WS105, WS112 and WS114.
	On site fuel pipelines.	TP102, TP108, TP109, TP110, TP112, TP131, TP133, TP134, TP134A, TP138, TP140, WS117 and WS120.
	On site infilled former pond.	TP134 and TP134A.
	Off-site farm yard.	TP114, TP136, WS115 and WS116.
	Off-site former brick works.	WS107-WS112, WS117 and WS118.
GROUND FEATURES TARGETED	On site infilled former canal.	TP121, TP122, TP124, TP125, WS105, WS112 and WS114.
	On site infilled former pond.	TP134 and TP134A.
	General site coverage.	TP101-TP142 and WS101-WS120.

CONTAMINATION SAMPLING PLAN	Based on the proposed end use, the sampling and analysis plan is more positively biased towards near surface samples as these represent the soils most likely to be available to future site users. The analysis is more biased towards the Made Ground samples as this stratum represents the soils most likely to be contaminated. The analytical frequency has been increased for samples around the on site infilled former canal and pond, on site fuel pipelines and the off-site farm yard as these represent the most likely area for contamination.
ANALYSIS PLAN	Given the site's history as a farm land with a infilled former canal and pond and based on the potential contaminants identified within the Hazard Identification section of the Phase 1 contamination assessment, BRD has scheduled a suite of typically occurring contaminants. In addition to this given that fuel pipelines cross the site BRD has scheduled a targeted suite of contaminants fuel pipelines with contaminants, including petroleum hydrocarbons and benzene, toluene, ethylbenzene and xylene (BTEX) compounds. In addition the samples have been analysed for methyl tertiary butyl ether (MTBE) which is a chemical which was added to unleaded petrol as an alternative to lead.

3.2. BRD FIELDWORK

TRIAL PITS	
REFERENCES	TP101 to TP142.
DEPTH RANGE	From 0.60m to 3.60m.
EXCAVATOR	JCB 3CX style wheeled backactor.
BACKFILL	All the trial pits were backfilled with arisings upon completion and compacted with rams of the excavator bucket.

WINDOWLESS SAMPLING BOREHOLES	
REFERENCES	WS101 to WS120.
DEPTH RANGE	From 1.65m to 5.45m.
RIG TYPE	Premier Drilling Rig.
INSTALLATION / BACKFILL	Boreholes WS102, WS106, WS108, WS110, WS112 and WS120 were backfilled with arisings only. Boreholes WS101, WS103-WS105, WS107, WS109, WS111 and WS113-WS119 had monitoring wells installed. These comprised 50mm nominal diameter standpipes fitted with a gas tap finished with a flush metal cover. The slotted response length of the well is shown on the individual logs. Bentonite seals are also indicated on the logs. The filter medium used was pea gravel.

LIGHT WEIGHT DEFLECTOMETER	
REFERENCES	LWD101 (TP105) to LWD104 (TP108).
DEPTH RANGE	0.60m.
METHODOLOGY	Lightweight Deflectometer.

MONITORING	
TYPE	Ground gases. Vapour. Groundwater monitoring.
DATES	24 th , 30 th October, 7 th November 2023.
GROUNDWATER SAMPLING METHOD	Samples were retrieved using a sampling bailer dedicated to each well.

3.3. LABORATORY TESTING

GEOTECHNICAL TESTING	
The soil samples for geotechnical testing were forwarded to the laboratory of Soil Property Testing Ltd with pH and sulphate analysis undertaken at the laboratory of DETS Ltd. The geotechnical testing suite is detailed below. The UKAS accreditation of the individual test methods is shown on the laboratory test report included in the Appendices.	
TEST	NUMBER OF SAMPLES TESTED
Moisture content	16
Liquid and plastic limits	16
Particle size distribution by wet sieve	2
Particle size distribution by wet sieve and hydrometer	2
pH and Water soluble Sulphate	12
Total Sulphur and Sulphate	12

SOIL CHEMICAL TESTING	
The soil samples for contamination and chemical geotechnical testing were forwarded to the laboratory of DETS Ltd and the testing suite is detailed below. The UKAS or MCERTS accreditation of the individual test methods is shown on the laboratory test report included in the Appendices.	
SOIL TESTS	NUMBER OF SAMPLES TESTED
Arsenic, Cadmium, Chromium, Chromium VI, Copper, Lead, Mercury, Nickel, Selenium, Zinc	25
Speciated Polycyclic Aromatic Hydrocarbons (PAH)	25
Arsenic	5
Total Petroleum Hydrocarbons (TPH) with full carbon banding and aliphatic/aromatic split	9
Benzene, Toluene, Ethylbenzene and Xylenes (BTEX) plus Methyl Tert Butyl Ether (MTBE)	9
Fibrous Material Screen (for Asbestos)	4
Semi-Volatile Organic Compounds (SVOCs)	4
Organochlorine Pesticides	10

GROUNDWATER CHEMICAL TESTING	
The water samples for chemical geotechnical testing were forwarded to the laboratory of DETS Ltd and the testing suite is detailed below. The UKAS or MCERTS accreditation of the individual test methods is shown on the laboratory test report included in the Appendices.	
WATER TESTS	NUMBER OF SAMPLES TESTED
pH	4
Sulphate	4

4. GROUND CONDITIONS

4.1. OVERVIEW

The ground conditions encountered differed from the published geology maps with the Oxford Clay Formation not encountered anywhere on the site with the underlying Kellaways Formation (comprising of the Kellaways Sand Member and the Kellaways Clay Member) encountered across the whole of the site.

Typically, the Kellaways Sand Member was recorded comprising silty fine sand beds sandwiched between orange brown to light grey sandy clay or clayey silt beds. The contact with the underlying Kellaways Clay Member is transitional in the region and so has been arbitrarily delineated. It is also possible that some of the surface soils represent a form of superficial deposits or geologically reworked bedrock. The underlying Kellaways Clay Member was typically recorded as a clay with variable sand content in the upper metres becoming a dark grey clay with depth.

Once the final layout is completed further and more detailed investigation might be considered in order to provide a better delineation of the contact between the Kellaways Sand and the Kellaways Clay Members.

Based on the published geology maps a major geological fault, the Chippenham Fault, crosses Chippenham town from northwest to south east but apparently ends to the west of the site and the recorded ground conditions have not identified any potential material developed as a result of the fault.

A thin cover of Topsoil and Made Ground Topsoil was encountered across the whole of the site, with Made Ground soils encountered to a maximum depth of 2.40m below ground level (m bgl) within the infilled former canal present on the site.

Details of the various stratigraphic units are given in the following sections.

4.2. ARTIFICIAL GROUND

Made Ground was encountered within the infilled former canal, located in the south of the site to depths of between 0.90m bgl and 2.40m bgl. The Made Ground was typically encountered as two distinct units described below:

The first Made Ground unit was typically described as firm to stiff, brown mottled orange brown, slightly sandy, silty clay with occasional brick, limestone and ceramic gravel with rare charcoal and coal fragments.

The second Made Grounds unit was typically encountered underlying the first strata and was typically described as soft to firm in parts, slightly organic, dark brown, silty clay with occasional coal, wood and shell fragments and rare brick gravel.

Ceramic land drains were encountered in trial pits TP116 and TP134 at a depth of 0.80m bgl and in TP135 at a depth of 1.80m bgl.

4.3. TOPSOIL AND MADE GROUND TOPSOIL

Topsoil and Made Ground Topsoil were encountered across the whole of the site to depths of between typically 0.20m and 0.35m and to a depth of 0.80m bgl in trial pit TP134, located within an infilled former pond.

The Topsoil was typically described as either dark brown, silty clay or sandy clay with many rootlets.

The Made Ground Topsoil was typically described as either dark brown, silty clay or sandy clay with many rootlets and rare glass, brick, sandstone or charcoal fragments.

4.4. BEDROCK

4.4.1. Kellaways Sand Member

The Kellaways Sand Member was encountered across most of the site typically in the topographically elevated areas underlying the Topsoil, Made Ground Topsoil or Made Ground but also in the southern most part of the site. The bedrock was encountered to depths of between 1.20m bgl and 2.50m bgl but typically to about 2.0m depth with thicknesses ranging from 0.90m to 2.20m. Maximum thicknesses were typically recorded in the upper areas of the site.

The Kellaways Sand Member was variable in nature but typically comprise sandy silty clay to clayey silt beds, orange brown to light grey mottled orange in colour with occasional silty fine sand pockets. In the upper areas these beds were intercalated by silty fine sand beds of typically 1m of thickness but in the lowest areas these sandy beds were of about 0.3m thickness when present as they were mostly absent towards the lowest areas of the site. Underneath, grey mottled orange brown to grey, clayey very sandy silt beds were recorded on top of the Kellaways Clay Member.

It is worth noting that in trial pit TP134A at 1.3m depth a medium strong, grey, coarse grained, shelly limestone bed was recorded and could not be excavated.

Natural black wood fragments were recorded in trial pit TP131 between 1.8m and 2.1m depth in sandy silty soils and at the contact between the Kellaways Sand Member and the Kellaways Clay Member.

The most commonly encountered and noteworthy units are described below:

- Firm to stiff, some friable, orange brown mottled light grey, sandy to very sandy, silty to very silty CLAY with rare fine dark red brown, ferruginous sandstone nodules.
- Soft, orange brown with occasional light grey, very sandy, silty CLAY with pockets of clayey, silty, fine sand.
- Stiff, light grey mottled orange brown, slightly sandy in parts, silty to very silty CLAY.
- Medium dense, orange brown to light grey mottled orange brown and light grey, silty to very silty, fine SAND.
- Stiff, light grey mottled orange brown, silty CLAY.
- Firm, , grey brown mottled orange brown, slightly sandy, very silty CLAY to very sandy SILT with pockets of silty fine sand
- Stiff, orange brown mottled light grey becoming light grey mottled orange brown, slightly sandy, silty CLAY.

4.4.2. Kellaways Clay Member

The Kellaways Clay Member was encountered across the whole of the site underlying the Kellaways Sand Member but also below the Topsoil in the lowest areas and to the western boundary. This bedrock was proven to a maximum investigation depth of 5.45m bgl.

As mentioned above the boundary between both Members of the Kellaways Formation has been arbitrary as there is a gradational change between both strata. Therefore, when this stratum has been recorded from surface typically orange mottled light sandy clays have been recorded and rare pockets of orange brown mottled grey, clayey, silty sand with occasional ferruginous sandstone gravel have been recorded intercalated such in in borehole WS118 at 1.50m depth. Then, these superficial units tuns into a light grey mottled orange brown with depth typically with abundant sand sized selenite crystals and rare mudstone gravel lithorelicts.

Below, stiff, closely fissured, grey brown mottled brown to dark grey silty clay has been recorded with silt sized yellow sulphide deposits possible remaining from above leached selenite crystals.

With depth the Kellaways Clay Member was typically described as stiff, closely fissured, grey to dark grey, silty to very silty clay with fine shell fragments and rare selenite crystals which occasionally were of fine to medium gravel size.

Occasionally, large cementstone nodules of septarian were recorded in trial pits TP122, TP133 and TP135 at depths between 1.9m and 2.9m and likely recorded in borehole WS117 at 2.65m which refused in a competent material. Likewise, occasional natural black wood fragments were recorded in the bedrock such in WS103 below 0.9m depth.

There is potentially some near surface superficial deposits or geologically reworked bedrock that may include deposits derive from superficial landslides. An example is in borehole WS110 below the topsoil to 0.7m depth. These deposits are a result of downhill material movements within clay soils and are characteristic by the presence of small natural black iron-rich minerals of gravel size.

4.5. **GEOTECHNICAL COMMENTS**

There is deep Made Ground associated with the infilled canal that will impact foundation depths and pavement design.

The Kellaways Sand Member were recorded as highly variable deposits, the granular units of which were prone to spalling and localised collapse typically on encountering the groundwater that may lead to construction difficulties.

Rare limestone beds were recorded associated with the Kellaways Sand Member. This bedrock is characterized by the presence of impersistent limestone or sandstone beds or variable thickness. This may cause difficulty in excavations in some areas.

4.6. **CONTAMINATION OBSERVATIONS**

No visual or olfactory evidence of contamination was noted during the forwarding of exploratory holes.

4.7. GROUNDWATER BEHAVIOUR

During the progressing of exploratory holes, the following general observations of groundwater behaviour were made. It is worth noting that the site investigation works were undertaken during a period of very wet weather.

Slightly seepages were recorded at the contact between the Topsoil and the underlying Kellaways Clay Member in the eastern and lowest area of the site in trial pits TP106, TP129, TP137. In this area too, seepages within the Kellaways Clay Member were recorded at 1.2m depth in trial pits TP102 and TP103.

Occasional seepages were recorded in the Kellaways Clay Member at depths of 2.9m in TP122 and TP139, lowest and upper areas of the site, respectively. Moist soils were recorded in borehole WS117 at 2.9m depth in the north eastern boundary.

A rushing groundwater inflow was recorded on completion of trial pit TP130 at 2.1m depth rising to 0.7m depth. The pit was completely excavated into the impervious Kellaways Clay Member which was recorded with mudstone gravel lithorelicts between 1.8m and 2.4m depth. However, based on the location of the pit, close to the drain/ditch which crosses the site from north east to south, it is considered that the water ingress came from the ditch and entered the pit through the soil disturbance caused by the excavation and at the level of the mudstone gravel lithorelicts which could behave as permeable material.

Typically, seepages were recorded at the base of the Kellaways Sand Member and close to the contact with the Kellaways Clay Member at depths between 1.2m and 2.2m bgl. Moist soils were recorded in borehole WS115 (lowest southern area) and in boreholes WS118 and WS119 (north eastern boundary) at depths between 1.0m and 1.4m. Seepages at shallower depths of between 0.5m and 1.0m were recorded in trial pits TP139 to TP141 in the north eastern boundary of the site.

Perched groundwater was encountered at the base of Made Ground recorded in trial pit TP121 and groundwater level with wet soils was recorded in borehole WS114 in the Made Ground.

4.8. GROUNDWATER MONITORING

DATE	RESTING GROUNDWATER RANGE	COMMENTS
24/10/23	From 0.15m to 4.21m bgl.	Typically, shallow standing groundwater levels at less or at about 1m depth have been recorded in most of the monitoring wells. Deepest standing groundwater levels, below 4m depth were recorded in boreholes WS111 and WS116, located in the western boundary and centre of the site, respectively. Borehole WS107 was recorded dry at an installation depth of 4.2m bgl. The monitoring visit followed a period of very wet weather.

DATE	RESTING GROUNDWATER RANGE	COMMENTS
30/10/23	From 0.10m to 4.02m bgl.	Shallower standing groundwater levels were recorded in all of the boreholes. Of particular note is borehole WS101 which was recorded flooded and borehole WS119 which recorded with standing water at about 0.1m depth. Boreholes WS09, WS114, WS117 and WS119 were purged to their installation base in the previous visit but have been recharged to similar or shallower levels than the previous visit. Borehole WS107 recorded dry previously was recorded with a standing groundwater level at 1.27m depth bgl. Shallower levels were recorded in borehole WS116 rising to about 3m depth. The monitoring visit followed a period of very wet weather.
07/11/23	From 0.05m to 3.14m bgl.	Shallower standing groundwater levels were recorded in all the boreholes. Boreholes located along the north eastern boundary and in the lowest areas of the site were recorded with standing water at depths between 0.05m and 0.3m bgl. Rising levels continuing in borehole WS116 reaching 1.34m depth. Standing water levels were slightly deeper in borehole WS107. The monitoring visit followed a period of very wet weather.

5. GEOTECHNICAL PROPERTIES

5.1. LIGHT WEIGHT DEFLECTOMETER (LWD)

Four LWD tests were undertaken at different locations of the proposed main access road which crosses the site from south to north across the eastern section of the site. The tests location is presented on the Exploratory Point Plan included in Appendix 1. The LWD test records are included in Appendix 2.

The superficial soils were removed by mechanical digging before undertaking the tests. Therefore, all the tests were undertaken at depths of 0.60m bgl, targeting the underlying natural soils of the Kellaways Sand (KS) or Kellaways Clay (KC) Members.

The LWD generates a dynamic soil modulus (Evd) from which can be correlated to a CBR value and to the Plate Bearing Test (Ev2). The relationship is derived from various sources and using software provided by 'Zorn Instruments', the LWD manufacturer. The Evd and correlated CBR and Ev2 values for each test are provided below.

LWD TEST	DEPTH (m) bgl	SOIL	Evd (MPa)	CBR (%)	Ev2 (MPa)
LWD01 (TP105)	0.6	Firm to stiff, slightly silty clay (KS)	8.45	3	17
LWD02 (TP106)	0.6	Firm, slightly silty clay (KC)	8.98	4	18
LWD03 (TP107)	0.6	Firm to stiff, slightly silty clay (KC)	10.06	4	20
LWD04 (TP108)	0.6	Firm to stiff, slightly silty clay (KC)	7.92	3	16

All the tests were undertaken in similar clayey soils and then similar values have been obtained. The dynamic soil modulus values range between about 8.45MPa and 10.06MPa. The correlated CBR values range from 3% to 4%. The correlated Plate Bearing Test values, Ev2, range between 16MPa and 20MPa.

It should be noted that both correlations between Evd/CBR and Evd/Ev2 are theoretical relationships and should be treated as approximate values.

5.2. STANDARD PENETRATION TESTS

A total of 96No. Standard Penetration Tests (SPTs) were undertaken in the windowless sampling boreholes carried out across the site.

In the Made Ground deposits recorded in the infilled former canal 4No. SPTs were carried out and N-values between 0 and 11 were recorded indicating very soft to stiff soils. The heterogeneity of this material is reflected in the variable N-values recorded.

A limited number of seven SPTs were carried out in the Kellaways Sand Member. Typically, the tests were undertaken in the upper 2m within the clay units and N-values ranging from 6 to 14 were recorded indicating firm to very stiff soils.

A refusal N-value (N>50) was recorded in borehole WS118 at 1.65m and it has been associated with the presence of an impersistent rock bed of limestone or sandstone sporadically recorded elsewhere across the site in the trial pits which are common within the Kellaways Sand Member.

The majority of the SPTs were carried out in the Kellaways Clay Member. A total of 85No. SPTs were undertaken. The N-values were highly variable but representing the different soil types recorded in these deposits, from sand clays to hard clays/mudstone.

N-values between 2 and 18 were recorded at about 1m depth, averaging N=10 which is indicative of stiff soils. The lowest N-value of 2 was recorded in WS120 at 1.2m depth but it is considered a misleading value not representative of these soils and should not be considered.

Below, between 2m and 3m depth, N-values ranging from 7 and 34 were recorded, averaging 16, which is indicative of stiff to very stiff soils. At 4m and 5m depth, N-values ranging from 11 and 30 were recorded, averaging 20, which is indicative of very stiff soils.

In boreholes WS113 and WS117 refusal values ($N > 50$) were recorded at 5m and 3m depth. Boreholes WS113 is considered to have refused in competent mudstone bedrock whereas borehole WS117 is likely to have refused in a large septarian concretion which were occasionally recorded in the trial pits at similar depths.

5.3. COARSE SOIL PARAMETERS

5.3.1. Particle Size Distribution (PSD)

The grading curves of the four samples of sand beds recorded in the Kellaways Sand Member subject to PSD determination revealed the soil to be poorly graded, slightly gravelly (or absent) silty fine sands. The gravel content was very low ranging from 0% to 2% content. High sands content ranging from 73% to 95%, typically more of 70% of fine sands, was recorded and a fines content of 3% to 27%, of which between 11% and 15% was of silt fraction.

5.4. FINE SOIL PARAMETERS

5.4.1. Index Property Testing

SOIL TYPE	Kellaways Sand Member – clay units.
PLASTICITY INDEX (PI)	13% and 17% (Two samples: low volume change potential). 26% - 28% (Three samples: medium volume change potential).
MODIFIED PI	Not applicable – no oversize particles.
COMMENTS	An average PI = 22% was recorded which is considered representative of this soil type.
NHBC CLASS	Medium volume change potential.

SOIL TYPE	Kellaways Clay Member.
PLASTICITY INDEX (PI)	23% - 38% (Nine samples: medium volume change potential). 46% (One sample: high volume change potential).
MODIFIED PI	11% (One sample: low volume change potential).
COMMENTS	A modified PI = 11% was recorded due to the elevated content in fossil shell fragments of sand and gravel size and should not be considered representative of these soils. Overall, an average PI = 29% was recorded which is considered representative of this soil type.
NHBC CLASS	Medium volume change potential.

5.4.2. Undrained Shear Strength

This section discusses all of the laboratory and in-situ tests that produce either direct or indirect measures of undrained shear strength.

5.4.2.1. *Hand Penetrometer*

SOIL TYPE	Kellaways Sand Member – clay units.
DISCUSSION OF CORRECTED RESULTS	The recorded hand penetrometer values range between 1.0 and 4.5 kg/cm ² . Values variation is due to the sand content in these soils. The recorded undrained shear strength was in the range of 25kPa and 113kPa which is indicative of low to high strength soil type.

SOIL TYPE	Kellaways Clay Member.
DISCUSSION OF CORRECTED RESULTS	The recorded hand penetrometer values range between 1.0 and >4.5 kg/cm ² . Typically, values increase with depth. In the upper metre, the recorded undrained shear strength was in the range of 31kPa and >120kPa, averaging 77kPa which is indicative of high strength soil type. Between 1.0m and 2.0m depth, the recorded undrained shear strength was in the range of 25kPa and >120kPa, averaging 76kPa which is indicative of high strength soil type. Between 2.0m and 3.0m depth, the recorded undrained shear strength was in the range of 3125kPa and >120kPa, averaging 76kPa which is indicative of high strength soil type. Between 3.0m and 4.0m depth, the recorded undrained shear strength was in the range of 55kPa and >120kPa, averaging 91kPa which is indicative of high strength soil type. Below 4.0m depth, the recorded undrained shear strength was in the range of 63kPa and >120kPa, averaging 99kPa which is indicative of high strength soil type.

5.4.2.2. Hand Shear Vane

SOIL TYPE	Kellaways Sand Member – clay units.
CORRECTION FACTOR μ	$\mu = 0.98$
JUSTIFICATION	After Bjerrum 1972, employing Plasticity Index.
DISCUSSION OF CORRECTED RESULTS	In the upper metre, the recorded undrained shear strength was in the range of 40kPa and 119kPa, averaging 79kPa which is indicative of high strength soil type. Below, up to 1.5m depth testing, the recorded undrained shear strength was in the range of 45kPa and 88kPa, averaging 66kPa which is indicative of medium strength soil type. The lower values are a result of the more sand and silt content recorded within the clay units, typically increasing with depth.

SOIL TYPE	Kellaways Clay Member.
CORRECTION FACTOR μ	$\mu = 0.93$
JUSTIFICATION	After Bjerrum 1972, employing Plasticity Index.
DISCUSSION OF CORRECTED RESULTS	In the upper metre, the recorded undrained shear strength was in the range of 48kPa and 78kPa, averaging 65kPa which is indicative of medium strength soil type. Below, between 1m and 2m depth, the recorded undrained shear strength was in the range of 52kPa and 107kPa, averaging 73kPa which is indicative of medium strength soil type. Then, up to 3m depth of testing, the recorded undrained shear strength was in the range of 54kPa and >140kPa, averaging 92kPa which is indicative of high strength soil type.

5.4.2.3. Standard Penetration Test Correlations

The SPT N-values have been corrected to N_{60} -values, and then correlated to an equivalent undrained shear strength (c_u) using the approach by Stroud (1985) based upon a relationship of $c_u = a \times N_{60}$. The “a” factor was of 5.0 for the Kellaways Sand Member and of 4.5 for the Kellaways Clay Member. Values selected based on the average plasticity index recorded from these soils.

A hammer efficiency value of $E_r=91\%$ was implemented for the windowless sample rig. The E_r -value was based on the annual calibration certificate provided by the sub-contractor.

For the Kellaways equivalent undrained shear strength values ranging between 46kPa and 106kPa, indicating medium to high strength, have been inferred.

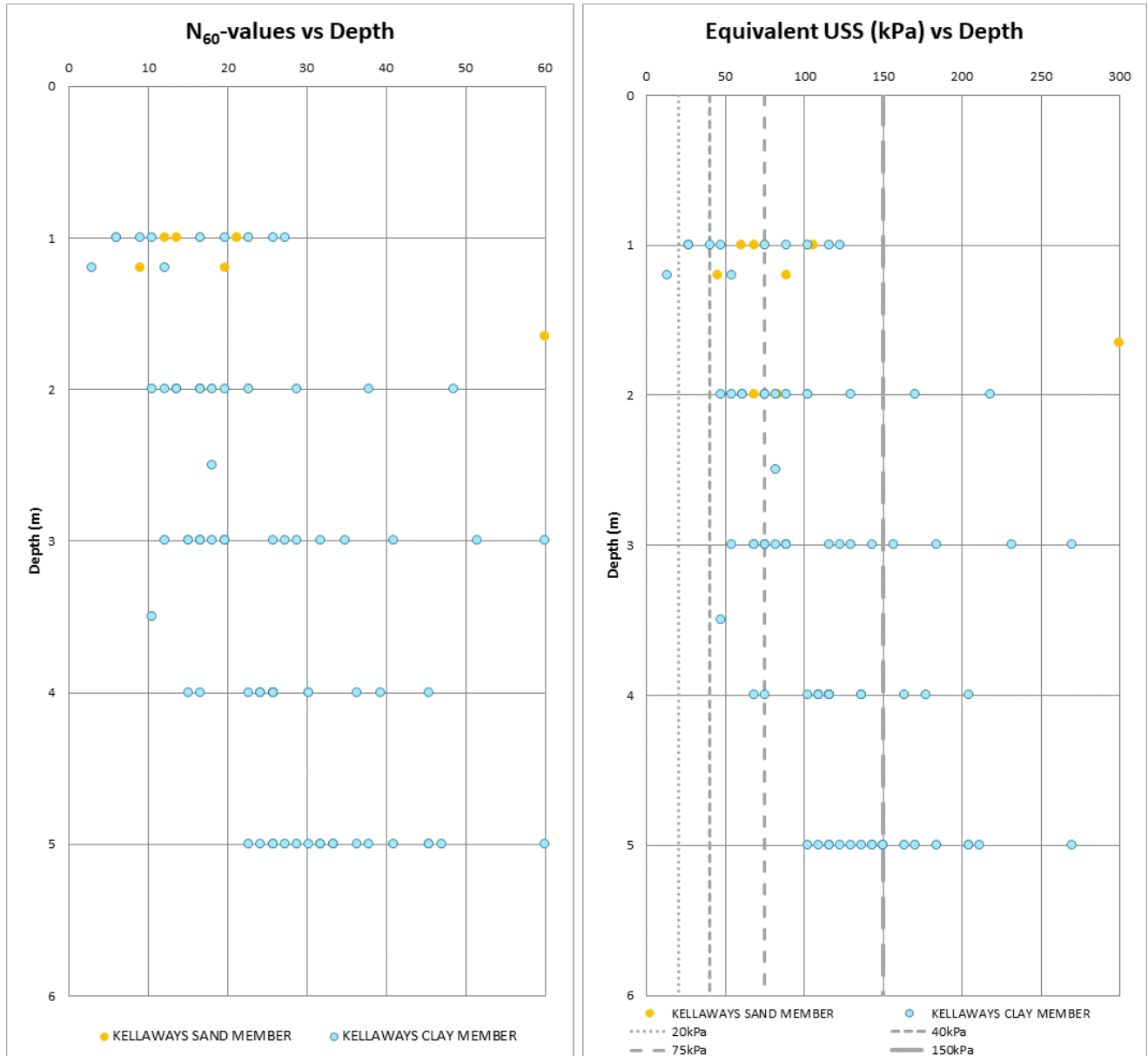
The Kellaways Clay Member in the upper metre has been recorded with equivalent undrained shear strength values ranging between 14kPa and 123kPa, indicating low to high strength. Typically, values lower than 40kPa (low strength soils) were recorded in the lowest section of the site which has been recorded with associated shallow standing groundwater.

At 2m depth, equivalent undrained shear strength values ranging between 55kPa and 218kPa, indicating medium to very high strength have been recorded.

At 3m depth, equivalent undrained shear strength values ranging between 48kPa and 232kPa, indicating medium to very high strength have been recorded.

Between 4m and 5m depth, equivalent undrained shear strength values ranging between 68kPa and 212kPa, indicating medium to very high strength have been recorded.

The following charts show the distribution with depth of the N_{60} -values considered in every borehole together with the derived equivalent undrained shear strength values. N_{60} -values and Equivalent USS values for the refusal N-values ($N > 50$) have been limited to $N_{60} = 60$ and $USS = 300$ kPa for a practical representation.



5.5. SULPHATE AND pH

	MADE GROUND / TOPSOIL / KELLAWAYS SAND MEMBER			
	Sulphate		pH	
Characteristic Value	190 mg/l		6.2 units	
Justification	Mean of highest 20% results rounded to nearest 100mg/l.		Mean of lowest 20% results.	
	No. of tests	Results Range	No. of tests	Results Range
Soil	27	<10 - 382 mg/l	27	5.8 - 7.8 units
Groundwater	2	46 - 59 mg/l	2	7.4 - 7.5 units
Total Potential Sulphate	-	Not applicable as pyrite unlikely in the samples tested.		

	KELLAWAYS CLAY MEMBER			
	Sulphate		pH	
Characteristic Value	9.24%		units	
Justification	Based Highest on Total Potential Sulphate.		Mean of lowest 20% results.	
	No. of tests	Results Range	No. of tests	Results Range
Soil	10	12 - 2,020 mg/l	10	4.2- 8.1 units
Groundwater	2	204 - 844 mg/l	2	6.7 - 7.3 units
Total Potential Sulphate	8	0.36% - 9.24% Five out of eight samples potentially pyritic.		

6. GEOTECHNICAL ASSESSMENT

6.1. INTRODUCTION

The following advice and recommendations are based on the construction of a large residential estate comprising low-rise residential properties. At this stage a final development layout has not been provided, however, an 'Illustrative Masterplan' is included in Appendix 1 where areas subject to development are shown. From assessment of the nature of the ground conditions and the type of proposed structures, it is considered that the situation falls within EC7 Geotechnical Category 1.

Should the nature of the development be changed then the results of this investigation would need to be reviewed and reassessed.

6.2. EXCAVATIONS

STABILITY	Any excavation requiring man entry should be battered back to a safe angle, supported by an appropriate proprietary trench support system or adequately shored to provide safe working conditions. Shoring to any excavation requiring man entry must be designed by a suitably qualified and experienced engineer. Any support system will require regular inspection as detailed in published guidelines to ensure the excavation support is adequate and appropriate for the ground conditions present. It is anticipated that narrow trench excavations will remain relatively stable and open for short periods, but minor spalling of side walls could still occur. Where deep Made Ground is present, such in the areas of the infilled former canal, it is anticipated that excavations will be prone to sidewall collapse and will require temporary support to remain open. Trench excavations encountering the groundwater are likely to suffer side wall collapse within the Kellaways Sand Member. The presence of land drains and their damage during the excavations triggered this behaviour too. Excavations below the water table within these deposits are likely to result in excavation difficulties due to 'running sands' and appropriate groundwater control will therefore be required. Water should not be allowed to collect in the base of any excavations as the clay soils are likely to suffer a significant strength reduction.
EQUIPMENT	Generally, it should be possible to progress excavations with conventional equipment. Sporadically shallow impersistent rock beds associated with the Kellaways Sand Member might be present in the upper areas of the site and so the use of hydraulic breaking equipment will likely be required for forwarding excavations through these units.

GROUNDWATER CONTROL	It is anticipated that groundwater control in the form of pumping from sumps formed in the base of excavations will be required. Any groundwater control system should be designed and operated to minimise the loss of fines from the soil matrix as this could adversely affect settlement. Under shallow groundwater conditions, it is considered that construction without adequate groundwater control will be problematical and that pumping from sumps alone may not be sufficient. Consultation with groundwater control contractors is recommended as specialist measures such as 'well pointing' may be required. Any groundwater control system should be designed and operated to minimise the loss of fines from the soil matrix as this could adversely affect settlement. Due to the shallow groundwater and slope across the site, it may be prudent that a system of land drainage is installed to intercept and divert shallow groundwater around proposed structures in advance of construction. Groundwater levels at the time of construction will have a critical impact on the ease of which the structure can be built. It is therefore recommended that groundwater monitoring is undertaken to assess the variation in the water table with seasonal or short term weather effects.
PARTY WALL ISSUES	To be confirmed once the final layout has been completed.

6.3. SLOPE STABILITY

The scope of this investigation excludes a formal slope stability study and the following observations are made for information only.

What seems to be superficial deposits that may have been derived from superficial landslips have been observed. Although no obvious signs of instability were observed within the site itself during the fieldwork it is recommended that a further ground investigation is undertaken by a senior geologist in order to confirm the extent and nature of these deposits if any more present.

South western site boundary is the top of an embankment from an open former brick pit which comprises a woodland. It is recommended that the proposed scheme includes a landscape buffer zone alongside the western boundary in order to avoid any slope instability immediately beyond this boundary which may encroach into the site itself.

Level changes as part of the development are anticipated. Any change in levels required should be cut to a slope no greater than one in four (vertical : horizontal) (14°) which should provide reasonable long term stability. It should be noted that shallower slopes may be required for other reasons such access in gardens. Alternatively, changes in level should be supported by appropriately designed and constructed retaining walls.

6.4. EARTHWORKS

It is likely that some earthworks will be required on site due to the existing site levels and the proposed development that will require some form of cut and fill to form development platforms. However, details of such earthworks have not been provided at this point.

Due to the variable topography, it is likely that the lowest development areas will be generally raised to facilitate road, drainage and services infrastructure. Some of the fill required for this operation will be generated from the excavation of the surface water attenuation basins located in the eastern part of the site.

Where substantial (+/- 1m) earthworks are required, then an earthworks specification should be developed. Further soil classification tests and compaction tests will likely be required to develop such a specification.

Alongside an earthworks specification, it is recommended that a Materials Management Plan is formulated in accordance with the CLAIRE "Definition of Waste: Development Industry Code of Practice" for the site to allow re-use of the site materials that could otherwise be classified as waste.

6.5. SUB-SURFACE CONCRETE

KELLAWAYS SAND MEMBER	
SITE / SOIL CATEGORY	Natural ground.
DESIGN SULPHATE CLASS	DS-1
GROUNDWATER REGIME	Mobile.
ACEC CLASS	AC-1

KELLAWAYS CLAY MEMBER	
SITE / SOIL CATEGORY	Natural ground containing pyrite.
DESIGN SULPHATE CLASS	DS-4
GROUNDWATER REGIME	Mobile.
ACEC CLASS	AC-5
COMMENTS	Concrete in pyritic ground that is initially low in soluble sulphate does not have to be designed to withstand a high potential sulphate class unless ground disturbance is such that pyrite may be oxidised. This may prompt a change in construction e.g. employing piled foundations instead of trench fill footings. The restriction to DS-4 has been applied.

6.6. SOAKAWAYS

6.6.1. Soil Infiltration Rate

The records of the soakage tests are presented in the Appendices that includes the calculation of the soil infiltration rate. A summary of results are presented in the table below:

TRIAL PIT	SOIL INFILTRATION RATE		STRATUM TESTED
TP101	Test 1	Permeability too low to calculate soil infiltration rate.	0.60m - 1.30m: Stiff, light grey mottled orange brown, slightly silty CLAY. 1.30m - 1.20m: Stiff, light grey with occasional orange brown mottling, silty CLAY with selenite crystals.
TP102	Test 1	Permeability too low to calculate soil infiltration rate.	0.25m - 1.20m: Firm, orange brown mottled light grey, slightly sandy in parts, silty CLAY. 1.20m - 1.50m: Firm, light grey with occasional orange brown mottling, silty CLAY with many fine, sandy sized selenite crystals.
TP103	Test 1	Permeability too low to calculate soil infiltration rate.	0.35m - 1.50m: Firm, orange brown mottling light grey, slightly silty CLAY with rare relict rootlets.
TP104	Test 1	Permeability too low to calculate soil infiltration rate.	0.30m -0.80m: Firm to stiff, orange brown mottled light grey, slightly sandy, silty CLAY. 0.80m - 1.20m: Soft, moist, orange brown with occasional light grey, very sandy, silty CLAY. 1.20m - 1.50m: Stiff, fissured, light grey mottled orange brown, silty CLAY with occasional calcareous concretions.

6.6.2. Soakaway Design Advice

Soakage tests were undertaken targeting the proposed attenuation ponds along the eastern half of the site. Due to the clayey nature of the soils recorded from surface all the soakage pits were unable to record any infiltration rate and then failed.

All the attenuation ponds will be mostly constructed within the clayey soils of the Kellaways Clay Member but limited sandy clay soils might be present in the upper metres and then slight seepages might be recorded. Therefore, the upper parts of the basins will need to be re-engineered with clay to prevent the seepages entering the basins. Likewise, any pond located in close proximity to the existing ditch will require to be re-engineering to avoid water infiltrations similar to those recorded in trial pits undertaken in this investigation.

Similar ground conditions have been recorded across the site with limited beds of fine sandy soils in the upper and western part of the site. However, these sand beds have been recorded sandwiched between clay rich soils at depths typically between 1m and 2m bgl and with limited thicknesses of between 0.3m and 1.0m. Therefore, it is considered that the disposal of collected surface water to soakaways will not be feasible at this site due to the cohesive nature and proved low permeability of the underlying soils.

6.7. PAVEMENT CONSTRUCTION

Due to the depth of made ground recorded along the infilled former canal, it is recommended that a preliminary design California Bearing Ratio (CBR) of less than 2% is assumed at this stage when present. Geo-grid reinforcement of the pavement construction is recommended in the canal area to limit differential settlement.

From consideration of the observed ground conditions and the plasticity of the clay soils recorded across the site, it is recommended that a preliminary design California Bearing Ratio (CBR) of 3% is assumed. The cohesive deposits will be prone to rapid degradation during wet weather working and this should be avoided where possible. It is worth noting that CBR values between 3% and 4% were obtained in the Lightweight Deflectometer plate tests.

The upper Kellaways Sand Member should be considered a frost susceptible soil and therefore a minimum total pavement construction of 450mm is required.

All unsuitable soils, such as topsoil or desiccated soils, should be removed from beneath proposed paved areas. The exposed sub-grade formation should then be proof rolled to reveal any excessively soft or compressible zones and any such features identified also removed by excavation. Where unsuitable materials are removed, the resultant voids should be filled in layers with appropriately compacted suitable granular fill. To reduce the loss of granular construction materials into the sub-grade, consideration should be given to utilising a geotextile starter layer across the formation level.

6.8. PRELIMINARY FOUNDATION RECOMMENDATIONS

6.8.1. Introduction

Variable ground conditions have been recorded across the site. Typically, the upper areas are dominated by the Kellaways Sand Member which comprises highly variable soils ranging from silt, clay to fine sands. Underneath, the Kellaways Clay Member is recorded which near surface comprises sandy clay to clay soils becoming a very stiff dark grey clay with depth. An illustrative ground conditions plans is included in Appendix 1.

Despite the variation, the ground is generally suitable for the use of conventional footings.

Relatively shallow standing groundwater level has been recorded across the site typically associated with the Kellaways Sand Member but also related to the Kellaways Clay Member in the lowest areas. This may cause construction difficulties.

Where structures straddle different soil types, sands to clay, mainly within the Kellaways Sand Member, then light mesh reinforcement will be required.

Variable in depth Made Ground has been recorded in the areas of the former infilled canal and pond, trench footings should be suitable for any plot straddling such features.

Within the zones of influence of the trees deepened trench fill foundations are considered appropriate. However, where plots are located adjacent to the trees and hedges piled foundations may need to be considered if trench fill foundations are too deep to be economic or practical to construct.

6.8.2. Floor Slabs

In consideration of the near surface clay soils, fully suspended floor slabs designed and constructed in accordance with NHBC Standards are recommended at this development.

Due to the depth of Made Ground recorded along the infilled former canal or the backfilled pond, fully suspended floor slabs designed and constructed in accordance with NHBC Standards are recommended for any plot located over or straddling these deposits.

With reference to Section 2.2, the floor construction will not have to incorporate radon gas protection measures.

6.8.3. Traditional Footings

The site is suitable for the adoption of shallow strip/trench fill footings. Foundations should be taken through made ground/topsoil to bear upon either the Kellaways Sand or the Kellaways Clay Member.

As a consequence of the variability and locally present lower strength deposits, it is considered prudent to assume a conservative presumed bearing value of 100kN/m² to account for the variability of the soils which will be found at formation level. Immediate and long term settlement should be within tolerable limits and take place largely during the construction period where granular formation deposits predominate, but with settlements occurring over an extended period where fine grained soils are prominent at formation level.

Due to the rapid potential variation in ground conditions likely to be encountered, from sand to clayey soils in the Kellaways Sand Member but also in the upper metres of the Kellaway Clay Member when recorded from surface, in order to take account of the variability in soils at formation level it is recommended that nominal (mesh) reinforcement is included within the foundation to reduce the effects of differential settlement across varying strata and distribute stresses more evenly around footings arising from structural loadings.

The natural soils across the site, the bedrock deposits of the Kellaways Sand and Kellaways Clay Members, have been shown to range from non-shrinkable (sand beds) to medium volume change potential soils (clay beds) when assessed against NHBC standards. Due to the extent of the sand beds, it is limited to the northern part of the site but also are sandwiched between clay beds, then it is considered suitable to consider the entire site with a medium volume change potential.

Therefore, the minimum foundation depth required is 0.90m, but 1.25m where required to allow for restricted new tree planting. Under the NHBC Standards, foundation depths have to be increased if they are within the influence zone of felled trees, existing trees or proposed tree planting. It should be noted that where trees are in groups the resulting competition for resources can lead to deeper root systems than allowed for in the NHBC Standards. In any event, foundations should be taken below any roots encountered in foundation trench excavation. Where the required foundation depth varies around a structure, this can be accommodated by forming steps in the foundation as per NHBC Standards.

Where foundation depths exceed 1.50m in clay soils and are within the zone of influence of existing or felled trees or where foundations cut through tree roots, a compressible void former will be required against the internal faces of new foundations in order to accommodate potential long term soil heave. Such precautions against heave should be designed and constructed in accordance with NHBC Standards.

The excavator must be set up with care and operated correctly to ensure trench walls are vertical and base horizontal as any slight inclination will result in eccentric loading on deep trench fill footings.

A number of trees and hedges are located across the site. It will be necessary to remove all unwanted trees, stumps and root structures prior to commencing with the development. Any resultant void should be backfilled accordingly with respect to the preferred foundation design.

Ground water level within the standpipes indicates that a shallow groundwater is present, generally between 0.05m and 4.20m depth across site. Excavations encountering groundwater seepage or perched water at the site rapidly become unstable and this will thus complicate the construction of the footings. The ease of construction will be dependent upon actual groundwater levels present at the time of construction. As a consequence of this, it is recommended that construction of footings is avoided in sustained wet periods and the winter months when groundwater can be expected to be at its shallowest. If problems are encountered then a 'dig and pour' approach may be required or in extreme cases adopting a piled solution. It is an inherent risk of 'dig and pour' that spoil disposal and concrete volumes could increase and professional supervision is also required. To minimise instability the length of trench open at any one time can be reduced by adopting a two part solution. The first is a lower mass pour trench fill is constructed using a semi-dry concrete that can be progressed segmentally around the plot. A thin reinforced strip footing can then be constructed upon the mass fill element once it has set.

During construction, any soft spots found at foundation formation level should be excavated and replaced with lean mix concrete. Foundation excavations should be kept dry and left open for the minimum amount of time possible. Where foundations cannot be completed immediately, a blinding layer of concrete should be placed.

6.8.4. Piling

For plots located in close proximity to trees, such as the woodland on the western site boundary and hedges which includes high water demand oaks, it may be necessary to consider a piled design where depth of trench fill foundations are too costly or instability of deep excavations and groundwater inflows present problems for construction of trench fill foundations.

Therefore, further investigation including deep cable percussive boreholes might be necessary to identify particular plots which could require piled foundations once the final development layout had been finalised.

6.9. RECOMMENDATIONS FOR FURTHER GEOTECHNICAL WORK

The boundaries between the Kellaways Sand and the Kellaways Clay Members have been only approximately delineated. Once the final layout is completed further a more detailed investigation should be considered in order to increase exploratory points density and to provide a better delineation of the contact between both strata.

Further ground investigation by a senior experienced geologist should be undertaken to determine the extent, nature and significance of potential superficial deposits that may include landslide derived material.

Once development levels are determined further investigation in areas of significant cut will be required for earthworks design.

Where piling is the foundation solution further deep borehole ground investigation will be required for design.

7. RISK ESTIMATION - SOILS

7.1. HUMAN HEALTH

The Generic Assessment Criteria (GAC) employed below are for residential land use as this is appropriate to the proposed form of development.

CONTAMINANT	UNITS	NUMBER OF TESTS	MAXIMUM CONCENTRATION	GAC	NUMBER EXCEEDING GAC
Arsenic	mg/kg	30	20	37	0
Cadmium	mg/kg	25	0.6	22	0
Chromium (total)	mg/kg	25	26	910	0
Chromium (hexavalent)	mg/kg	25	<2	21	0
Copper	mg/kg	25	29	2,400	0
Lead	mg/kg	25	196	200	0
Mercury	mg/kg	25	1.6	11	0
Nickel	mg/kg	25	25	180	0
Selenium	mg/kg	25	<2	250	0
Zinc	mg/kg	25	283	3,700	0
pH	Units	37	4.2	<5-10>	4
Naphthalene	mg/kg	25	<0.1	2.3	0
Acenaphthylene	mg/kg	25	<0.1	170	0
Acenaphthene	mg/kg	25	<0.1	210	0
Fluorene	mg/kg	25	<0.1	170	0
Phenanthrene	mg/kg	25	0.29	95	0
Anthracene	mg/kg	25	<0.1	2,400	0
Fluoranthene	mg/kg	25	0.59	280	0
Pyrene	mg/kg	25	0.56	620	0
Benzo(a)anthracene	mg/kg	25	0.25	7.2	0
Chrysene	mg/kg	25	0.40	15	0
Benzo(b)fluoranthene	mg/kg	25	0.36	2.6	0
Benzo(k)fluoranthene	mg/kg	25	0.19	77	0
Benzo(a)pyrene	mg/kg	25	0.35	2.2	0
Indeno(1,2,3-cd)pyrene	mg/kg	25	0.24	27	0
Dibenzo(a,h)anthracene	mg/kg	25	<0.1	0.24	0
Benzo(ghi)perylene	mg/kg	25	0.19	320	0
TPH Aliphatic C5-C6	mg/kg	9	<0.01	42	0
TPH Aliphatic C6-C8	mg/kg	9	<0.05	100	0
TPH Aliphatic C8-C10	mg/kg	9	<2	27	0
TPH Aliphatic C10-C12	mg/kg	9	<2	130	0
TPH Aliphatic C12-C16	mg/kg	9	<3	1,100	0
TPH Aliphatic C16-C35	mg/kg	9	<10	65,000	0
TPH Aliphatic C35-C44	mg/kg	9	<10	65,000	0

CONTAMINANT	UNITS	NUMBER OF TESTS	MAXIMUM CONCENTRATION	GAC	NUMBER EXCEEDING GAC
TPH Aromatic C5-C7	mg/kg	9	<0.01	70	0
TPH Aromatic C7-C8	mg/kg	9	<0.05	130	0
TPH Aromatic C8-C10	mg/kg	9	<2	34	0
TPH Aromatic C10-C12	mg/kg	9	<2	74	0
TPH Aromatic C12-C16	mg/kg	9	<2	140	0
TPH Aromatic C16-C21	mg/kg	9	<3	260	0
TPH Aromatic C21-C35	mg/kg	9	<10	1,100	0
TPH Aromatic C35-C44	mg/kg	9	<10	1,100	0
Benzene	mg/kg	9	<0.002	0.87	0
Toluene	mg/kg	9	<0.005	130	0
Ethylbenzene	mg/kg	9	<0.002	47	0
Xylene (total of all types)	mg/kg	9	<0.004	56	0
Methyl Tert Butyl Ether (MTBE)	mg/kg	9	<0.005	49	0
Semi-Volatile Organic Compounds (SVOCs)	mg/kg	4	None Detected	LOD*	0
Organochlorine Pesticides	mg/kg	10	None Detected	LOD*	0
Asbestos	Presence	4	<0.001	Fibres Present	0

Notes: *Limit of detection: Given the large amount of compounds in this group, coupled with the lack of GAC for certain compounds, any concentrations above the limit of detection will be highlighted in the first instance.

RESULTS EXCEEDING HUMAN HEALTH ASSESSMENT CRITERIA

pH

When compared to the generic assessment criteria (GAC) of pH <5-10>, a total of four elevated low pH were recorded in the Kellaways Clay Member at a pH of 4.2 in WS107 at 2.40m bgl and TP129 at 2.10m bgl, 4.3 in TP116 at 2.20m bgl and 4.5 in WS104 at 1.70m bgl.

A normality plot was undertaken which demonstrated that the pH for the 10No. samples of the Kellaways Clay Member approximated to a normal distribution. The maximum value test demonstrated that there are unlikely to be any statistical outliers.

It should be noted that pH is not a contaminant and only reflects the nature of the soils. The acidic pH values recorded are most likely associated with the natural geochemistry of the soils. These values do not present a cause for concern and does not need to be considered further.

7.2. WATER ENVIRONMENT

It is not appropriate to consider human health assessment criteria for human health in relation to the risk to the water environment, but currently there are no generic soil assessment criteria in respect of the water environment. In the absence of any groundwater sampling data, the soil results are assessed on the basis of professional judgement.

The contaminant concentrations recorded in the soils at the site are not considered to be at such levels that they would present any significant risk to the underlying water environment.

7.3. BUILDING MATERIALS

CONTAMINANT	UNITS	NUMBER OF TESTS	MAXIMUM CONCENTRATION	GAC	NUMBER EXCEEDING GAC
pH	units	37	4.2	<5.5	4
Sulphate (w/s)	mg/l	37	2020	500	4
Sum of SVOC + Aliphatic TPH >C5-C10 + Aromatic TPH >C5-C10 above detection limits	mg/kg	9	None Detected	2	0
Sum of Aliphatic TPH >C10-C21 + Aromatic TPH >C10-C21 above detection limits	mg/kg	9	None Detected	10	0
Sum of Aliphatic TPH >C21-C34 + Aromatic TPH >C10-C35 above detection limits	mg/kg	9	None Detected	500	0
Sum of BTEX + MTBE above detection limits	mg/kg	9	None Detected	0.1	0
Phenols	mg/kg	4	None Detected	2	0
Cresols and chlorinated phenols	mg/kg	4	None Detected	2	0
Naphthalene	mg/kg	25	<0.1	0.5	0
Benzo(a)pyrene	mg/kg	25	0.35	0.5	0

RESULTS EXCEEDING BUILDING MATERIALS ASSESSMENT CRITERIA

WATER SOLUBLE SULPHATE	Concentrations of water soluble sulphate are such that they could detrimentally impact sub-surface concrete. The impact on concrete mix design is a geotechnical issue that is considered separately and so no further comment is made on these results within this contamination assessment.
pH	The acidic pH values recorded are such that they could detrimentally impact sub-surface concrete. The impact on concrete mix design is a geotechnical issue that is considered separately and so no further comment is made on these results within this contamination assessment.

8. RISK ESTIMATION - GAS

8.1. RESULTS SUMMARY

The following table summarises the results from the initial three rounds of gas monitoring undertaken at the site. A further six visits are scheduled and this section of the report will be updated on their completion.

PARAMETER	MINIMUM	MAXIMUM	COMMENTS
Methane	0.0%	0.0%	No significant concentrations recorded.
Carbon Dioxide	0.1%	13.2%	Elevated concentrations of Carbon Dioxide have been recorded in boreholes WS105, WS107, WS111 and WS113. However, shallow groundwater was recorded in boreholes WS105 and WS113. The maximum concentration of Carbon Dioxide recorded to date in boreholes with deeper groundwater is 5.7%.
Oxygen	10.3%	21.8%	The oxygen levels were typically depleted as carbon dioxide concentrations increased.
Hydrogen Sulphide	0ppm	1ppm	No significant concentrations recorded.
Carbon Monoxide	0ppm	37ppm	Elevated concentrations of Carbon Monoxide have been recorded in boreholes WS101-WS105, WS109, WS113-WS115, WS117 and WS118. However, all of these elevated concentrations either occurred in boreholes where shallow groundwater was recorded or during the first monitoring visit which is likely to be due to drilling disturbance.
VOC - (PID)	0.0ppm	0.0ppm	No significant concentrations recorded.
Atmospheric pressure	990mB	1006mB	1No. of the 3No. monitoring visits completed to date has followed a period falling pressure, with one of the other monitoring visits undertaken following a period of rising pressure following an intense low pressure event.
Groundwater levels	0.01m	4.21m	Shallow groundwater has been recorded in boreholes WS101-WS105, WS109, WS113-WS115 and WS117-WS119. The groundwater was generally deepest in the highest western area of the site and generally shallowest in the lower eastern and southern areas of the site. The monitoring visits followed a period of very wet weather.

PARAMETER	MINIMUM	MAXIMUM	COMMENTS
Flow rate	-5.9l/hr	14.8l/hr	Elevated flow rates have been recorded in boreholes WS101-WS105, WS107, WS109, WS113-WS115 and WS117. However, all of these flow rates were recorded when shallow groundwater was recorded except for in borehole WS107 at a flow rate of 3.8l/hr during one monitoring visit. Negative flows are indicative of 'draw down' in the boreholes. These can be a factor of the effect of drilling on the immediate ground conditions, the creation of a partial vacuum as a result of monitoring, groundwater behaviour or due to certain geologic conditions. In terms of the contamination risk assessment, this does not present a cause for concern as the net effect is to reduce the emission of gas at surface.

SENSITIVITY OF DEVELOPMENT	High (Residential with gardens)	
	IDEALISED	ACTUAL
MONITORING PERIOD	6 months	1 month
TOTAL NUMBER OF VISITS	9 visits	3 visits
NUMBER OF VISITS DURING FALLING PRESSURE TRENDS	At least two visits	1 visit.
COMMENT	As two of the monitoring visits were not undertaken during a period of falling atmospheric pressure then further monitoring visits are recommended during such times to increase confidence in the results obtained to date. To date, only three of the scheduled gas monitoring visits have been completed. The three visits undertaken to date does enable a preliminary characterisation of the gas regime at the site. A further 6No. monitoring visits are recommended to comply with CIRIA C665. Very shallow groundwater has been recorded to date that has impacted both the recording of the gas emission rates and the duration of some of the gas tests. It would be preferable to undertake the additional monitoring when the groundwater levels have subsided after a period of drier weather. Consideration should also be given to raising monitoring wells to be above ground. Further monitoring may be subsequently recommended in the summer months, depending on the level of uncertainty still remaining after the full 9No. visits have been completed.	

8.2. GAS REGIME CHARACTERISATION

Based on the current data it is likely that some form of gas protection measures will be required in the southern area of the site where the infilled canal is present, but unlikely to be needed elsewhere. However, a full characterisation of the gas regime at the site is not possible at this stage.

This section will be updated once the full gas monitoring programme has been completed and gas regime characterisation is possible.

9. RISK EVALUATION

9.1. REVISED CONCEPTUAL MODEL

The revised conceptual site model plan is presented in the Appendices.

ADDITIONAL POLLUTANT LINKAGES	During the ground investigation, the Kellaways Sand Member was found to be present across most of the site typically in the topographically elevated areas, but also in the southern most part of the site. The Kellaways Sand Member is designated as a Secondary A Aquifer and as such represents a potential receptor with associated additional potential pollutant linkages now identified.
INVALID POLLUTANT LINKAGES	No significant soil contamination has been identified by this investigation. As such it is considered that the only likely potential pollutant linkages that remain are inhalation of landfill gasses (subject to further monitoring). The pollutant linkages associated with the underground fuel pipelines and the infilled former pond remain only because they could not be investigated due to the utility service exclusion zones.
LIMITATIONS AND UNCERTAINTIES	Due to access restrictions, it was not possible to undertake any exploratory holes within close proximity to any of the services present on the site. However, for the majority of the site all of the potential contamination sources have been targeted by the exploratory holes and therefore it is considered that a sufficient number of exploratory points have been completed for contamination assessment purposes. The exception is the underground fuel pipelines and the infilled former pond located within the pipelines and overhead electrical line exclusion zone as these two potential contamination sources could not be fully targeted at this time. Should the 30m exclusion zone agreed with Exolum be reduced significantly then investigation closer to the fuel pipelines and the infilled former pond could be undertaken to target these potential sources and to provide further confidence in the risk assessment. The current level of gas monitoring is insufficient to make an assessment of the risk, and therefore further monitoring will be required to complete the gas assessment and is scheduled to be completed. It would be preferable to undertake the additional monitoring when the groundwater levels have subsided after a period of drier weather. Consideration should also be given to raising monitoring wells to be above ground. Further monitoring may be subsequently recommended in the drier summer months, depending on the level of uncertainty still remaining after the full 9No. visits have been completed.

9.2. UPDATED CONTAMINATION RISK ASSESSMENT

The pollutant linkages identified in the revised conceptual site model will now be evaluated as to their severity:

SOURCES AND CONTAMINANTS	PATHWAYS (REFERENCE FROM MODEL)	RECEPTORS	POTENTIAL RISK
Infilled Canal -Metals. -Hydrocarbons. -Asbestos containing materials. -Landfill gases (mainly carbon dioxide and methane).	Ingestion	Residents	Negligible Risk
	Inhalation of dusts		
	Horizontal & vertical migration	Surface water	
		Groundwater	
	Direct contact	Building materials and services	
Infilled Canal -Landfill gases (mainly carbon dioxide and methane).	Inhalation of landfill gases (1)	Residents	Moderate to Low Risk (subject to completion of scheduled monitoring)
Underground Fuel Pipelines -Minor leaks from redundant fuel pipelines.	Ingestion	Residents	Low Risk (and localised to area along the length of the fuel pipelines only)
	Inhalation of dusts (2)		
	Inhalation of vapours (3)		
	Horizontal & vertical migration (4)	Surface water	Low Risk (and localised to area along the length of the fuel pipelines only)
		Groundwater	Low Risk (and localised to area along the length of the fuel pipelines only)
	Direct contact (5)	Building materials and services	Low Risk (and localised to area along the length of the fuel pipelines only)
Infilled Ponds -Metals. -Hydrocarbons -Asbestos containing materials. -Landfill gases (mainly carbon dioxide and methane).	Ingestion	Residents	Low Risk (but localised to infilled pond within pipelines and overhead electrical line exclusion zone only)
	Inhalation of dusts (6)		
	Inhalation of landfill gases (7)		Low Risk (subject to completion of scheduled monitoring)
	Direct contact (8)	Building materials and services	Low Risk (but localised to infilled pond within pipelines and overhead electrical line exclusion zone only)

SOURCES AND CONTAMINANTS	PATHWAYS (REFERENCE FROM MODEL)	RECEPTORS	POTENTIAL RISK
<u>Off Site</u> Migration of contaminants from the Farmyard -Hydrocarbons (diesel and heating oil) -Pesticides	Ingestion	Residents	Negligible Risk
	Inhalation of dusts		
	Inhalation of vapours		
	Direct contact	Building materials and services	Negligible Risk
<u>Off Site</u> Former brick works to the north of the site -Migration of soil gases from historic backfilling of clay pits.	Inhalation of landfill gases (9)	Residents	Moderate to Low Risk (subject to completion of scheduled monitoring)
	Direct contact	Building materials and services	Negligible Risk

The contamination risks that are presented to the various receptor groups are discussed further in the following sections:

RISK TO HUMAN HEALTH

No significant soil contamination has been identified during the investigation to date.

Ground Gas

Based on the current data it is likely that some form of gas protection measures will be required in the southern area of the site where the infilled canal is present, but unlikely to be needed elsewhere. However, a full characterisation of the gas regime at the site is not possible at this stage as shallow groundwater has been recorded to date that has impacted both the recording of the gas emission rates and the duration of some of the gas tests. The number of monitoring visits is limited.

Oil Pipelines

Whilst transmission pipelines could have leaked, the risk of such an occurrence is in fact very low. Whilst the hazard element of the risk is all too obvious, the likelihood of the hazard being realised is very low. This is because the engineering of transmission pipelines, even old ones, have always been very good as the consequence of a failure has always been well understood. Admittedly in the past this was focused on the economic consequences of a leak rather than the environmental impact of one.

Despite having dealt with many site over the years, BRD Consultants have never encountered a fuel/oil transmission pipelines (both active and redundant) that has caused contamination [Note this comment is specific to transmission pipelines only].

Any leakage from the pipeline would have been concentrated in the trench the pipe was installed in. The disturbance caused by the installation of a pipe causes the backfill around the pipe to always be more permeable than the surrounding ground. It is a well-recognised phenomena that utility trenches create preferential flow paths for contamination migration. So in the unlikely event that there is contamination associated with the pipelines, it will be restricted to the trenches. As one of the pipes remains live and the other derelict ones are within an easement that the development will have to accommodate, it is unlikely that their presence will present an issue as they will be located in public open space.

RISK TO WATER ENVIRONMENT

No significant soil contamination has been identified during the investigation to date.

Due to the 30m exclusion zone agreed with Exolum the underground fuel pipelines was unable to be fully investigated. Potential localised low risks to the water environment from the underground pipelines therefore remain flagged within the assessment, but as discussed are unlikely to be present in reality.

RISK TO BUILDING MATERIALS AND SERVICES

No significant soil contamination has been identified during the investigation to date.

Due to the 30m exclusion zone agreed with Exolum the underground fuel pipelines and infilled pond were unable to be fully investigated. Potential localised low risks to building materials and services remain from these potential sources therefore remain flagged within the assessment.

9.3. RISK MANAGEMENT

9.3.1. Introduction

No significant soil contamination has been identified during the investigation to date.

The exclusion zone of the live transmission pipeline and other services has restricted the contamination assessment. Should the exclusion zone be reduced significantly then further investigation of these potential sources should be undertaken.

Based on the current data it is likely that some form of gas protection measures will be required in the southern area of the site where the infilled canal is present.

It is recommended that this report is submitted to the planning department of the Local Authority, the organisation undertaking the Building Control function and warranty providers to confirm that the investigation completed to date is satisfactory.

9.3.2. Further Contamination Assessment

In order to provide further confidence in the risk assessment and to address the limitations and uncertainties identified within the existing conceptual model it is recommended that the following additional investigation elements are completed for contamination assessment purposes:

- In line with the guidance in CIRIA C665 it is considered that at least 6No. further monitoring visits will be required to fully evaluate the gas regime. It would be preferable to undertake the additional monitoring when the groundwater levels have subsided after a period of drier weather. Consideration should also be given to raising monitoring wells to be above ground. On completion of these visits, the gas risk assessment will be updated.
- If the 30m exclusion zone around the active transmission pipeline can be significantly reduced, it is considered that further exploratory points in the vicinity of the underground fuel pipelines and the infilled former pond would be prudent.

9.3.3. Outline Remediation Strategy

The need for any remediation will be dependent on the findings of the additional investigation described above, in particular the gas monitoring. Should any significant contamination risks be identified then a formal remediation strategy will need to be developed by an experienced Geo-Environmental Consultant. All remediation works should then be supervised and verified by an experienced Geo-Environmental Consultant. The remediation works should be documented in a Verification Report.

9.4. **WASTE SOIL DISPOSAL**

Topsoil should be viewed as a resource rather than a waste. As the topsoil is suitable for residential garden use in terms contamination, the topsoil at the site should be stripped and the surplus reused on other developments. It should be noted that topsoil, even if uncontaminated, is unlikely to constitute 'inert waste' due to its high organic matter content.

It is considered that the natural sub-soils disposed of from the site would be classified as 'non-hazardous waste' and would be characterised for disposal to landfill as 'inert waste'. However, the chemical results should be forwarded to the proposed landfill site and the waste classification confirmed prior to disposing of any surplus soils. Waste Acceptance Criteria (WAC) testing of the soils will also be required where the soil is to be disposed of at a landfill permitted to accept inert waste. The waste code from the European Waste Catalogue (EWC) 2002 for the soils would be 17 05 04 'Soil and Stones, not containing dangerous substances'.

It is considered that the Made Ground soils from the infilled former canal disposed of from the site would be classified as 'non-hazardous waste' and as such the waste will require pre-treatment prior to off-site disposal e.g. by selective excavation. The chemical results should be forwarded to the proposed landfill site and the waste classification confirmed prior to disposing of any surplus soils. The waste code from the European Waste Catalogue (EWC) 2002 for the soils would be 17 05 03 'Soil and Stones, containing dangerous substances'.

10. HEALTH AND SAFETY FILE INFORMATION

10.1. INTRODUCTION

The aim of the following sections is to present pertinent Health and Safety information that has arisen from the current investigation/survey works discussed in this report. The aim is to identify health and safety controls that may be necessary during any subsequent maintenance, refurbishment, demolition or construction works. The information is not exhaustive and stems only from the aspects identified within the scope of the works undertaken by BRD.

Where BRD has been appointed as a Principal Contractor, then this information shall form the Health and Safety Files as required by the Construction Design and Management (CDM) Regulations 2015.

Reports are always forwarded to the Client and they shall be responsible for ensuring this safety information is disseminated to those who need it.

The works undertaken by BRD are detailed in the previous sections of this report.

10.2. HAZARDS

During the course of the BRD works the following noteworthy safety hazards have been identified:

10.2.1. Contamination

Although no contamination has been identified, as with any construction site, if any anomalous material is encountered during the redevelopment then expert environmental advice should be sought.

10.2.2. Asbestos

In accordance with Health and Safety Executive (HSE) guidance, a 'Refurbishment Demolition Survey' (RDS) should be undertaken to identify whether or not asbestos containing materials are present in the existing structure(s) prior to demolition or refurbishment. The results of the survey should then be used to plan for the safe management, removal and disposal of asbestos containing materials from the existing buildings and infrastructure should such materials be present.

10.2.3. Other Issues

During the BRD works the following safety hazards were identified:

- All future works will need to consider the management of operations in the location of fuel pipelines. Regarding the live pipeline, all necessary guidance provided by the pipeline operator Exolum will need to be adhered to.
- There is evidence that the site is subject to trespass. Measures to secure the site should be taken so that trespassers are not at risk from the existing state of the site.

10.3. EXISTING STRUCTURES

BRD recommend that advice on existing structures is gained from a qualified and experienced Building Surveyor or Structural Engineer.

10.4. HAZARDOUS MATERIALS

BRD did not construct anything with hazardous materials.

Any soils to be imported to the site, in particular topsoil, should be tested to confirm their suitability in the development.

10.5. UTILITY SERVICES

No previously unidentified utility services were encountered during the BRD works.

The utility services plans held by the Client should be referred to.

The utility service companies should be contacted for records of their own equipment.

REPORT SPECIFIC REFERENCES

- 'Phase 1 Geo-Environmental Desk Study – Forest Farm, Chippenham', BRD Environmental Ltd, report ref. BRD2483-OR1-B, dated November 2023.
- British Geological Survey sheet 265 "Bath" Solid and Drift edition (1:50,000) published 2011.

SUPPORTING INFORMATION

GROUND INVESTIGATION

Exploratory holes are logged by an experienced Geo-Environmental Consultant in general accordance with 'Code of practice for site investigations' BS5930:2015, British Standards Institution, 2015. Soil samples for chemical and geotechnical analysis are taken from the exploratory holes at intervals dictated by the nature of the soils and the objectives of the investigation.

Where stated on the logs of inspection pits, trial pits or boreholes (where insitu testing has not been undertaken), the relative density of coarse (sand and gravel) soils is tentative only. Such assessments of density are on the basis of visual inspection only taking into consideration such factors as drilling rates, stability of pit side walls, appearance and behaviour under excavation.

Where Chalk strata is encountered it is logged and graded in general accordance with CIRIA guidance 'C574 - Engineering in Chalk'. It should be recognised that where percussive drilling methods are employed, the structure of the Chalk is destroyed and therefore the grading stated on such logs is either tentative or absent where it is not possible to assess the grade.

Hand Dug Inspection Pits

Hand tools are used to forward shallow inspection pits as a cost effective method of describing and sampling near surface soils. The technique is also used where exposure of existing footings is required. The depth reached by such techniques is a function of the nature of the ground and generally does not exceed 1.5m

Trial Pits

Mechanically excavated trial pits allow detailed inspection of near surface ground due to the large volume of soil exposed. A wheeled backhoe loader is the usual machine for digging trial pits that are typically 3 to 4.5m deep, 0.5m wide and 3m long.

Windowless Sampling Boreholes

This type of borehole is formed by a small tracked dynamic percussion drilling rig with samples retrieved in thin plastic liners within the narrow diameter steel sampling tubes. Borehole depths of up to 5m are typical, but in exceptional circumstances up to 15m depth can be achieved. This is the smallest type of rig that is capable of undertaking Standard Penetration Tests (SPTs).

Hand Held Window Sampling

Hand held window sampling is a useful method of drilling narrow diameter boreholes particularly where access is difficult. Hand held mechanical percussive hammers are used to drive the sampling tube into the ground. The soil samples are collected within the hollow metal sampling tubes and inspected via the open window along one side. Window sampling boreholes can be forwarded to depths of 3m to 6m depending upon ground conditions.

Cable Percussive Boreholes

This form of drilling involves repetitive dropping of a tube into the soil under its own weight from a tripod support. The sample is obtained from the clay cutter head in fine soils or a bailer for wet granular soils. As the borehole progresses SPTs can be undertaken and relatively undisturbed samples can be obtained. Typically these boreholes are 15 to 25m deep, but depths of double that can be achieved in soils, but only thin weak rock layers can be penetrated.



Rotary Boreholes

Where competent rock is required to be drilled then rotary drilling techniques are required. The drilling rigs can vary in size from small tracked units to larger units mounted on four wheel drive trucks. Rotary open hole drilling techniques break the rock into small fragments and so recovery of any samples is limited. In contrast, rotary coring retrieves excellent samples. Some rigs also allow windowless sampling to be undertaken through soil layers. There are no practical limits to the depths that this drilling method can achieve.

Dynamic Probing

Dynamic probing comprises a sectional rod with a sacrificial cone at the base of slightly larger diameter than the rod. The rod is driven into the ground by a constant mass falling through a set distance. The number of blows required to forward the rod per 100mm is then recorded and presented in a graph of N_{10} values. The standard applicable to dynamic probing is "BS EN ISO 22476-2:2005 Incorporating corrigendum no. 1, Geotechnical investigation and testing – Field testing – Part 2: Dynamic probing" BSi, February 2007.

Static Cone Penetration Tests

Cone Penetration Tests (CPT) consist of pushing a conical 60° cone into the ground at a constant rate and recording the force required to do this. Sensors in the cone record other information and this data can be correlated to a number of different geotechnical parameters.

Dynamic Penetrometer

The Transport Research Laboratory Dynamic Cone Penetrometer (TRL DCP) uses an 8 kg hammer dropping through a height of 575mm to drive a 60° cone of 20mm maximum diameter into the ground. The depth driven either per blow or per several blows is recorded. The strength of each of the soil layer encountered is then calculated by converting the penetration rate (mm per blow) into an approximate California Bearing Ratio (CBR) value employing the correlation proposed by TRL.

Gas Monitoring

Gas monitoring is undertaken with a portable gas monitor for oxygen, Methane, Carbon Dioxide, Hydrogen Sulphide and Carbon Monoxide together with recording of atmospheric pressure and any flow rate.

Vapour Monitoring

Headspace tests and monitoring for Volatile Organic Compounds (VOC) or Semi Volatile Organic Compounds (SVOC) is undertaken using a Photo Ionisation Detector (PID). The MiniRAE models used have a 10.6 eV lamp calibrated for isobutylene. The PID is useful tool to indicate the presence of a wide range of volatile compounds, but only provides semi-quantitative data as different compounds provide a different response and thus the reading is not a true reflection of the actual concentration present.

Low PID readings can be recorded in natural uncontaminated organic soils or even as a result of atmospheric pollution. It is generally accepted by consultants and regulators that recorded values in excess 50 parts per million (ppm) represents the presence of organic compound pollutants and in excess of 100 ppm such contamination may be significant.

The headspace test procedure involves the collection of a sample of suspected contaminated soils and placing within a sample bag. A tight seal to the bag is formed with a similar volume of air trapped to that of the soil and the sample is left for fifteen minutes to allow volatilisation of any contaminants. The bag is then pierced by, and sealed around, the sample probe of the PID and a reading taken.

Borehole well monitoring is undertaken by connecting the PID directly to the gas tap on the monitoring well installation.

Groundwater Level Monitoring

Groundwater levels are recorded with an electronic dip meter that has a detector end that is lowered into the borehole well. An audible signal is made when water is reached and the depth recorded from the graduated tape used to lower the detector. Where there is potential for a separate Light Non Aqueous Phase Liquid (LNAPL) to be present floating on the groundwater an oil/water interface meter is used in preference to a conventional dip meter so that any such floating product can be detected.

Geotechnical Sampling

BRD schedule a range of geotechnical testing as appropriate to the identified ground conditions, available budget and the proposed development. Different types of soil samples are obtained as appropriate to the ground conditions and planned testing.

SAMPLE TYPE	SYMBOL USED ON LOGS	DESCRIPTION
<i>Disturbed</i>	<i>D</i>	<i>Small disturbed soil samples of about 1 to 2 kg are collected in plastic bags.</i>
<i>Bulk</i>	<i>B</i>	<i>Large disturbed bulk samples up to about 20 to 30 kg are collected in plastic bags</i>
<i>Undisturbed</i>	<i>U</i>	<i>'Undisturbed' samples generally collected in plastic or metal tubes within cable percussive boreholes of 100mm diameter for samples of fine soils of firm to stiff consistency. Can also be representative of samples taken by cutting plastic sample liners from windowless sampling drilling methods. It is recognised that such samples do not generally meet Eurocode sample quality requirements for the tests commonly employed. However, given the wealth of experience with these sampling methods this continues to be common in United Kingdom practice particularly for less sensitive developments where more expensive sampling techniques are not economically justifiable.</i>
<i>Undisturbed</i>	<i>UT</i>	<i>A thin walled steel sampler developed by Archway Engineering called a UT100 in an attempt to gain better quality samples of soft to firm fine soils when using cable percussive drilling methods.</i>

Contamination Sampling

BRD schedule contamination testing as appropriate to the ground conditions, available budget, potential contaminants and the proposed development. Samples are collected in single use laboratory supplied containers.

Soil samples are retrieved in plastic containers and/or amber glass jars with a lined plastic cap. Contamination samples are indicated by a 'J' on exploratory hole logs.

Water samples are collected in plastic bottles and/or amber glass jars with a lined plastic cap then placed in cool boxes together with freezer packs. Water samples are indicated by a 'W' on exploratory hole records, but generally such samples are not tested as testing from dedicated monitoring wells is preferred for sample quality reasons.

Samples retrieved from the exploratory holes are dispatched to the laboratory by overnight courier. Where samples cannot be transported directly from site they are temporarily stored in the BRD dedicated sample storage facility which includes refrigeration where necessary. The individual accreditation of the test methods is detailed in the laboratory test report.

GEOTECHNICAL ASSESSMENT

Under Eurocode 7 (EC7) the following risk ranking is applied to geotechnical projects:

GEOTECHNICAL CATEGORY	DESCRIPTION
1	<i>Small and relatively simple structures for which it is possible to ensure that the fundamental requirements will be satisfied on the basis of experience and qualitative geotechnical investigations with negligible risk. For example, straightforward ground conditions, local experience, no excavation below the water table unless this will be straight forward.</i>
2	<i>Conventional types of structures and foundations. No difficult soil or loading conditions. Quantitative geotechnical data and laboratory testing. Routine procedures for field and laboratory testing. Conventional structures and no exceptional geotechnical risk. For example, spread, raft and piled foundations, retaining walls, bridge piers and abutments, embankments, ground anchors, tunnels and excavations.</i>
3	<i>Those structures not in Categories 1 and 2 such as very large or unusual structures, structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions. Structures in highly seismic areas. Structures in areas of probable site instability or persistent ground movements that require separate investigation or special measures.</i>

GEOTECHNICAL PARAMETERS

Soakage Tests

Soakage tests comprise the filling of a test pit with water and recording the time taken for the water to drain away. The tests are undertaken in general accordance with 'Digest DG 365: Soakaway design' BRE, Revised 2016. The test pits are usually gravel filled for safety with a slotted vertical pipe through which water observations are made. Water is generally supplied by a tanker to allow fast filling of the pits with water. Compliant tests are filled and allowed to drain near empty three times.

Standard Penetration Tests

The standard penetration test (SPT) determines the resistance of soils at the base of a borehole to the dynamic penetration of a split barrel sampler and the recovering of disturbed samples for identification purposes. In gravelly soils and some soft rocks a solid cone is used in preference to the sampler.

The basis of the test consists in driving a sampler by dropping a hammer of 63.5 kg mass on from a height of 760 mm. The number of blows (N value) necessary to achieve a penetration of the sampler of 300 mm is recorded. The test is described in 'Geotechnical investigation and testing — Field testing — Part 3: Standard penetration test - BS EN ISO 22476-3:2005 Incorporating corrigendum no. 1', BSi, 2007.

The uncorrected N values of the SPT tests are recorded upon the borehole logs together with a record of blows for each 75mm test portion including the seating blows. Where the full test depth cannot be achieved due to refusal on hard stratum, the number of blows and the distance achieved is recorded and the N value given as >50. The abbreviation SPT(c) is used upon the logs indicates that the test was performed with a solid cone rather than a split spoon sampler.

It is necessary to apply a correction to the N values to account for the effects of energy delivery using the equation: $N_{60} = \frac{E_r}{60} N$ where E_r is the energy ratio of the specific test equipment.

In the case of tests in sand, for the effects of overburden and rod length the equation is modified to $N_{60} = \frac{E_r}{60} \times \lambda \times C_N \times N$ where λ is the correction factor for energy losses due to the rod length and C_N is the correction factor for vertical stress due to overburden of the soil.

Sulphate

In order to compare the laboratory soil test results with 'Concrete in aggressive ground. BRE Special Digest 1: 2005' (BRE, 2005) laboratory results are converted to SO_4 mg/l. Laboratory results expressed as SO_3 g/l and are multiplied by a factor of 1200 to express the results as SO_4 mg/l.

Index Property Tests

In accordance with National House Building Council (NHBC) Standards Chapter 4.2 – Building near trees, the laboratory plasticity indexes are assessed against their volume change potential. The Modified Plasticity Index is defined as the Plasticity Index of the soil multiplied by the percentage of particles with a nominal diameter of less than $425\mu\text{m}$. Whilst the NHBC Standards were developed for residential buildings, the advice is equally applicable to a large number of other types of low rise structures.

Hand Shear Vane

The undrained shear strength of the fine (i.e. clay) soils at the site can be established using hand shear vane apparatus. Usually three readings are taken at every depth tested and the uncorrected results recorded on the exploratory point log. Shear vane readings from depths below 1.2m depth in trial pits are from tests performed on excavated soil. In accordance with Eurocode 7 – Geotechnical design – Part 2: Ground investigation and testing EN 1997-2:2007 the results should be corrected. BRD employ only simple correction methods as the more complex correction methodologies imply undue accuracy to a test that has distinct disadvantages and limitations.

Pocket Penetrometers

The Pocket Penetrometer is a lightweight instrument for use by field personnel to check visual classification of soils. It is a simple test and there is inherent uncertainty related to the small volume of soil being tested and so the results should be used with appropriate caution. Pocket penetrometers are calibrated in terms of unconfined compressive strength and once converted to undrained shear strength (divide by two) the results are further reduced by a factor of 1.5 - 2.0 as the device tends to overestimate strengths.

<i>Instrument Reading (uncompressive strength in kg/cm²)</i>	<i>Indicative Undrained Shear Strength (kN/m²)</i>	<i>Indicative Consistency</i>	<i>Indicative strength</i>
1.0	25 - 33	Soft	Low
1.5	38 - 50	Soft to firm	Low to medium
2.0	50 - 67	Firm	Medium
2.5	63 - 83	Firm to stiff	Medium to high
3.5	88 - 116	Stiff	High
4.5	113 - 150	Stiff to very stiff	High to very high

CONTAMINATION ASSESSMENT METHODOLOGY

UK Policy

The UK Government's policy in relation to land affected by historic contamination is based on a 'suitable for use' approach. The approach recognises that the risks presented by any given level of contamination will vary greatly according to the use of the land and a wide range of other factors, such as the underlying geology of the site. Contamination risks therefore need to be assessed on a site-by-site basis. The 'suitable for use' approach limits requirements for remediation to the work necessary to prevent unacceptable risks to human health or the environment in relation to either the current use or future use of the land.

The three main drivers for contamination assessment and remediation are:

- *Voluntary action.*
- *Development as part of the planning regime.*
- *Regulatory action to mitigate unacceptable risks e.g. Part 2A of the Environmental Protection Act 1990.*

Pollutant Linkages

For a contamination risk to exist there must be a 'pollutant linkage' from the contaminant (source) via a pathway (the route from contaminant to receptor) to a receptor (the entity that could be harmed). The absence of a contaminant, pathway or receptor breaks the pollutant linkage and therefore no contamination risk exists.

Contamination is typically present at a site (in the ground and/or in the underlying groundwater) as a result of a historic or current industrial use, usually as a result of leaks, spills or disposal of residues, wastes and excess raw materials from the industrial processes. Contamination may also be present due to:

- *The deliberate application of chemicals e.g. the spraying of herbicide/pesticide.*
- *Migration of pollutants from adjacent land.*
- *Naturally occurring processes e.g. elevated concentrations of particular heavy metals associated with specific geological strata.*

Conceptual Site Model

The conceptual site model can be defined as a textual or graphical representation of the identified pollutant linkages for a given site. The model forms the basis for designing the investigation as the aim will be to target all of the potential pollutant linkages to determine, through the subsequent phases of risk assessment, whether or not they pose an actual risk.

It is important that the conceptual site model is updated with new information as the various investigation, risk assessment and remediation works are completed.

Technical Guidance

The technical and legal framework for contamination assessment is complex. The process adopted through this report for assessing contamination risks is in general accordance with the following guidance, as listed below:

- 'Investigation of Potentially Contaminated Sites - Code of Practice - BS 10175:2011+A2:2017', The British Standards Institution 2017.
- Land Contamination Risk Management, Environment Agency, 2021.
- 'Guidance for the safe development of housing on land affected by contamination - R&D66: 2008', NHBC/Environment Agency, 2008.

Risk Assessment Methodology

In line with the technical guidance, the contamination risk assessment follows a series of phased stages for each particular site:

PHASE	DESCRIPTION	RISK ASSESSMENT STAGE
PHASE 1	Generally limited to desk based research and a site walkover survey to develop an initial conceptual site model and identify what risks, if any, are likely to be presented by the site.	Hazard Identification and Assessment A preliminary stage of risk assessment concerned with identifying and characterising the hazards that may be associated with a particular site and identifying potential pollutant linkages.
PHASE 2	This phase is concerned with establishing whether contamination is present, usually through intrusive ground investigation, and then evaluating the degree and magnitude of the associated risks.	Risk Estimation A stage concerned with estimating the likelihood that receptors will suffer adverse effects if they come into contact with, or are otherwise affected by, a hazardous substance or agent under defined conditions. Risk Evaluation A stage of risk assessment concerned with evaluating the acceptability of estimated risks, taking into account the nature and scale of the risk estimates, any uncertainties associated with the assessment and the broad costs and benefits of taking action to mitigate risks.
PHASE 3	The appraisal and selection of remediation techniques, their implementation and verification.	Risk Management The process whereby decisions are made to accept a known or assessed risk and/or the implementation of action to reduce the consequences or probabilities of occurrence.

Risk Classification

The objective of risk assessment is to identify the nature and magnitude of the potential risks and should be based on a consideration of both:

- The likelihood/probability of an event [taking into account both the presence of the hazard and receptor and the integrity of the pathway].
- The severity of the potential consequence [taking into account both the potential severity of the hazard and the sensitivity of the receptor].

There is a need for a logical, transparent and repeatable system in defining the categories of severity of consequence and likelihood as well as for the risk itself and therefore the following risk rating matrix is employed:

		SEVERITY OF CONSEQUENCE			
		SEVERE	MEDIUM	MILD	MINOR
PROBABILITY	HIGH LIKELIHOOD	Very High Risk	High Risk	Moderate Risk	Moderate/Low Risk
	LIKELY	High Risk	Moderate Risk	Moderate/Low Risk	Low Risk
	LOW LIKELIHOOD	Moderate Risk	Moderate/Low Risk	Low Risk	Negligible Risk
	UNLIKELY	Moderate/Low Risk	Low Risk	Negligible Risk	Negligible Risk

These risk classifications are defined as follows:

- **Very High Risk** - There is a high probability that severe harm could arise to a designated receptor from an identified hazard at the site without appropriate remediation action.
- **High Risk** - Harm is likely to arise to a designated receptor from an identified hazard at the site without appropriate remediation action.
- **Moderate Risk** - It is possible that without appropriate remediation action harm could arise to a designated receptor. It is relatively unlikely that any such harm would be severe, and if any harm were to occur it is more likely that such harm would be relatively mild.
- **Low Risk** - It is possible that harm could arise to a designated receptor from an identified hazard. It is likely that, at worst if any harm was realised any effects would be mild.
- **Negligible Risk** - The presence of an identified hazard does not give rise to the potential to cause harm to a designated receptor.

This risk assessment matrix and classification system is based on guidance produced by Department for Environment, Food and Rural Affairs (Defra) and the Environment Agency in connection with contaminated land assessment.

RISK ESTIMATION - SOILS

Introduction to Soil Human Health Generic Assessment Criteria (GAC)

The Environment Agency (EA) and Department of Environment Food and Rural Affairs (DEFRA) had previously issued revised guidance following the consultation about the DEFRA publication "Assessing risks from land contamination – a proportionate approach. Soil Guideline Values: the Way Forward". This resulted in a revised version of the Contaminated Land Exposure Model (CLEA) model (version 1.06) and a few of the previously published Soil Guideline Values (SGVs) were revised.

The main legislative driver for dealing with historical land affected by contamination is Part 2A of the Environmental Protection Act 1990. Revised Statutory Guidance to support Part 2A was published in April 2012. This Guidance introduced a new four-category system for classifying land under Part 2A for cases of a Significant Possibility of Significant Harm to human health,¹ where Category 1 includes land where the level of risk is clearly unacceptable and Category 4 includes land where the level of risk posed is acceptably low. The impact assessment for the new Statutory Guidance stated "The new statutory guidance will bring about a situation where the current SGVs/GACs are replaced with more pragmatic (but still strongly precautionary) Category 4 screening levels (C4SLs) which will provide a higher simple test for deciding that land is suitable for use and definitely not contaminated land". The C4SLs are still derived using the CLEA model, but adopt a slightly different approach to toxicological assessment and exposure modelling.

In March 2014, the outcome of "SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination - Final Project Report" (CL:AIRE) was published. Due to slightly ambiguous wording within this report, Lord de Mauley, Parliamentary Under Secretary, DEFRA wrote to all local authorities on 3 September 2014 to confirm that the published C4SLs were final and that they can be used in risk assessment undertaken under the planning regime.

Whilst there are proposals for the industry to develop C4SLs for other contaminants, these have yet to produce any new values. BRD do not believe that C4SLs could be developed by a single organisation with sufficient confidence. BRD has therefore employed other, more conservative guidance based on the CLEA model (detailed below) within this assessment for compounds where C4SLs are not available. However, it should be noted that the results of this investigation may need to be reinterpreted as new C4SLs become available.

Due to the limited number of published C4SL values at this time, the Chartered Institute of Environmental health (CIEH) and Land Quality Management Ltd (LQM) have produced Generic Assessment Criteria (GAC) known as Suitable for Use Levels (S4ULs), for use in contaminated land human health risk assessment. These S4ULs (2014) have been derived for a large number of substances using the current CLEA model and are therefore consistent with current guidance. They also incorporate the revised exposure parameters as adopted by the C4SL programme, but have not adopted the revised toxicological approach adopted by the C4SLs and so remain a more conservative assessment criteria. The substances for which SGVs were previously published have also been revised as new S4ULs in light of the new exposure parameters proposed by the C4SL programme, and therefore effectively replace the existing SGVs.

In addition, in December 2009, other GAC for less common substances were produced by the Environmental Industries Commission (EIC), The Association of Geotechnical and Geoenvironmental Specialists (AGS) and Contaminated Land: Applications in Real Environments (CL:AIRE) using the CLEA model. These are referred to as the EIC/AGS/CLAIRE GAC.

In summary, C4SLs have been used where these are available. For those substances where C4SLs have yet to be issued, then the S4ULs have been adopted or in some cases, the EIC/AGS/CLAIRE GAC. All of the previously produced SGVs have now either been withdrawn, or superseded by the respective C4SLs or S4ULs.



The only exception to this approach is the PAH compound benzo(a)pyrene (BaP) where a C4SL guideline value has been produced, whereas BRD has adopted the S4UL value. The C4SL for BaP relates to its use as a surrogate marker compound representing all of the genotoxic PAH compounds as a mixture, rather than this individual compound. BRD has therefore adopted the compound specific S4UL value as the initial screening value, for consistency with the other PAH compounds before then employing the C4SL is necessary.

It should be noted that unless otherwise stated, all the assessment criteria adopted within this report have been derived based on a sandy loam soil at pH 7 and the values quoted are for a conservative soil organic matter content of 1% where applicable (i.e. organic contaminants).

Human Health - Soil Generic Assessment Criteria

The results of the soils analysis have been compared to generic assessment criteria for the default exposure scenarios comprising either residential land with plant uptake, residential land without plant uptake, or commercial/industrial land use. The criteria values selected are listed in the table below and full details on the source are referred to above. Where applicable, the results have also been assessed with reference to the required statistical tests presented within CLAIRE document "Guidance on comparing soil contamination data with a critical concentration".

ANALYSIS	GENERIC ASSESSMENT CRITERIA (mg/kg unless stated)			SOURCE
	RESIDENTIAL WITH PLANT UPTAKE	RESIDENTIAL WITHOUT PLANT UPTAKE	COMMERCIAL / INDUSTRIAL	
Arsenic	37	40	640	C4SL
Cadmium	22	150	410	
Chromium (total) ^s	910	910	8,600	S4UL
Chromium VI	21	21	49	C4SL
Lead	200	310	2,330	
Mercury*	11	15	320	S4UL
Selenium	250	430	12,000	
Nickel	180	180	980	
Copper	2400	7,100	68,000	
Zinc	3,700	40,000	730,000	
pH	<5 - 10> units			Professional judgement
Naphthalene	2.3	2.3	190	S4UL
Acenaphthylene	170	2,900	83,000	
Acenaphthene	210	3,000	84,000	
Fluorene	170	2,800	63,000	
Phenanthrene	95	1,300	22,000	
Anthracene	2,400	31,000	520,000	
Fluoranthene	280	1,500	23,000	
Pyrene	620	3,700	54,000	
Benzo(a)anthracene	7.2	11	170	
Chrysene	15	30	350	
Benzo(b)fluoranthene	2.6	3.9	44	
Benzo(k)fluoranthene	77	110	1,200	
Benzo(a)pyrene	2.2	3.2	35	
Indeno(1,2,3-cd)pyrene	27	45	500	
Dibenzo(a,h)anthracene	0.24	0.31	3.5	S4UL
Benzo(ghi)perylene	320	360	3,900	
TPH Aliphatic C5-C6	42	42	3,200	
TPH Aliphatic C6-C8	100	100	7,800	
TPH Aliphatic C8-C10	27	27	2,000	
TPH Aliphatic C10-C12	130	130	9,700	
TPH Aliphatic C12-C16	1,100	1,100	59,000	
TPH Aliphatic C16-C35	65,000	65,000	1,600,000	
TPH Aliphatic C35-C44	65,000	65,000	1,600,000	

ANALYSIS	GENERIC ASSESSMENT CRITERIA (mg/kg unless stated)			SOURCE
	RESIDENTIAL WITH PLANT UPTAKE	RESIDENTIAL WITHOUT PLANT UPTAKE	COMMERCIAL / INDUSTRIAL	
TPH Aromatic C5-C7	70	370	26,000	
TPH Aromatic C7-C8	130	860	56,000	
TPH Aromatic C8-C10	34	47	3,500	
TPH Aromatic C10-C12	74	250	16,000	
TPH Aromatic C12-C16	140	1,800	36,000	
TPH Aromatic C16-C21	260	1,900	28,000	
TPH Aromatic C21-C35	1,100	1,900	28,000	
TPH Aromatic C35-C44	1,100	1,900	28,000	
Benzene	0.87	3.3	98	C4SL
Toluene	130	880	56,000	S4UL
Ethylbenzene	47	83	5,700	
Xylene^	56	79	5,900	EIC/AGS/CL:AIRE GAC
MTBE	49	73	7,900	

Notes:

* The S4UL for methyl mercury has been adopted as the worst case mercury compound as generally there is no desk study evidence to suggest the potential for elemental mercury on the majority of sites.

^ The lowest S4UL of either p-xylene, o-xylene or m-xylene has been adopted for each land use as a conservative measure.

§ S4UL for Chromium III adopted, as in the absence of Chromium VI it is likely that all of the chromium will be in this form as these are the two most common and stable forms of chromium in the soil environment.

Where no GAC is available, any concentrations exceeding the laboratory limit of detection are identified and discussed in more detail.

Water Environment - Soil Generic Assessment Criteria

There are no UK published Generic Assessment Criteria for soil test results in respect of the risk to the water environment and therefore risk estimation is on the basis of the professional judgement and experience of BRD to employ values that are a reasonable concentration above which concern for water resources is valid.

The Total PAH GAC employed is the sum of the 16No. priority PAH compounds regularly tested for in contaminated land analysis (i.e. US EPA 16PAHs). BRD employ a soil screening based upon the total PAH limit for 'inert waste' of 100mg/kg. The rationale is based on PAHs are recognised to be generally of low solubility and the risk to the water environment is correspondingly low.

In respect of Total Petroleum Hydrocarbons, BRD employ a value of 500 mg/kg as a screening value in comparison to the sum of the component aliphatic and aromatic TPH carbon bands. The employed soil screening value is based upon:

- In common with some other consultants, the professional judgement and experience of BRD suggests that this value is a reasonable concentration above which concern for water resources is valid. The rationale is based on the fact that lower concentrations of fuel based contaminants are more likely to naturally degrade than migrate any great distance.
- BRD is aware of regional Environment Agency groundwater and contaminated land teams historically employing 500 mg/kg as a screening value for considering whether or not TPH could represent a risk to water resources.
- The value mirrors the mineral oil Waste Acceptance Criteria limits for what is considered 'inert waste'.



Should elevated contaminants that pose a potential risk to the water environment be identified then site specific assessment criteria should be developed.

Building Materials and Services – Soil Generic Assessment Criteria

Some hydrocarbon compounds are known to both attack and permeate through certain plastic pipe materials, with the primary concern being the degradation and tainting of water supplies. The UK Water Industry Research (UKWIR) has therefore produced a document ‘Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites’ (ref. 10/WM/03/21) that specifies threshold criteria for the adoption of ‘standard’ polythene (PE) or PVC pipes, protective barrier pipe and ductile iron/steel/copper pipes.

The UKWIR threshold assessment criteria from Table 3.1 of this document for standard PE pipes have been employed. It should be noted that the approach taken by UKWIR is very conservative, and both the document and research are flawed. However, it is these values that are being using to specify water pipe materials and therefore it is appropriate to consider them.

The UKWIR guidance is particularly flawed in respect of the chemical analysis it expects as it seeks a limit of detection that is generally below limits that are reasonable or commonly employed in contaminated land assessment. The UKWIR seeks that where a substance is below the limit of detection it should be taken as being present at half this concentration. For the larger suite of chemicals where the limit is against a sum of compounds, this approach would mean that a sample of virgin sub-soil from a greenfield site with absolutely no contamination would actually fail the criteria for using standard PE pipes. To avoid this situation, BRD have adopted the approach of summing only those compounds detected above their respective limits of detection.

In terms of building materials, the primary concern is in respect of concrete as certain commonly occurring natural ground conditions can adversely impact on buried concrete as discussed in ‘Special digest 1:2005 Concrete in aggressive ground’, BRE, 2005.

ANALYSIS	GENERIC ASSESSMENT CRITERIA	SOURCE
<i>pH</i>	<i><5.5</i>	<i>BRE Special Digest 1:2005</i>
<i>Sulphate (w/s)</i>	<i>500 mg/l</i>	<i>BRE Special Digest 1:2005</i>
<i>Sum of any VOC above detection limits</i>	<i>0.5 mg/kg</i>	<i>Relevant compounds adapted from UKWIR Table 3.1</i>
<i>Sum of SVOC + Aliphatic TPH >C5-C10 + Aromatic TPH >C5-C10 above detection limits</i>	<i>2 mg/kg</i>	
<i>Sum of Aliphatic TPH >C10-C21 + Aromatic TPH >C10-C21 above detection limits</i>	<i>10 mg/kg</i>	
<i>Sum of Aliphatic TPH >C21-C34 + Aromatic TPH >C10-C35 above detection limits</i>	<i>500 mg/kg</i>	
<i>Sum of BTEX + MTBE above detection limits</i>	<i>0.1 mg/kg</i>	
<i>Phenols</i>	<i>2 mg/kg</i>	
<i>Cresols and chlorinated phenols</i>	<i>2 mg/kg</i>	
<i>Naphthalene</i>	<i>0.5 mg/kg</i>	
<i>Benzo(a)pyrene</i>	<i>0.5 mg/kg</i>	

RISK ESTIMATION - GROUNDWATER

The initial assessment of the contamination risk to groundwater is by comparing dissolved groundwater concentrations with screening values (GAC) that are protective of groundwater resources.

The reference source for the target concentrations is generally the EA's Environmental Quality Standards (EQS) (accessed July 2018: <http://evidence.environment-agency.gov.uk/ChemicalStandards/report.aspx?cid=17>), the Water Supply (Water Quality) Regulations 2016 and the DW1/DW2 criteria from the Surface Water (Abstraction for drinking water)(classification) Regulations 1996. The target concentrations are outlined in the table below. The 'Petroleum Hydrocarbons in Groundwater: Guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies'. CL:AIRE, 2017 has also been used as reference source for the values.

ANALYSIS	GENERIC ASSESSMENT CRITERIA (GAC)	SOURCE
Arsenic	50 µg/l	DW1 & EQS
Cadmium	5 µg/l	EQS
Chromium (total)	50 µg/l	DW2 & EQS
Copper	50 µg/l	DW1
Nickel	20 µg/l	EQS
Lead	50 µg/l	DW1
Mercury	1 µg/l	WSR
Selenium	10 µg/l	WSR
Zinc	5 mg/l	DW2
Cyanide	50 µg/l	WSR
pH	6 to 9 units	EQS
Benzene	10 µg/l	EQS
Toluene	74 µg/l	EQS
Ethylbenzene	300 µg/l	WHO guideline
Xylene	30 µg/l	EQS
Methyl tert-butyl ether (MTBE)	15 µg/l	Taste and odour threshold.
Naphthalene	2 µg/l	EQS
Benzo(a)pyrene	0.0017 µg/l	EQS - Less than Limit of Detection (LOD)
Total PAH	0.2 µg/l	DW1
TPH Aliphatic C5-C6	15,000 µg/l	World Health Organization (WHO) guide values for TPHCWG fractions in drinking water
TPH Aliphatic C6-C8	15,000 µg/l	
TPH Aliphatic C8-C10	300 µg/l	
TPH Aliphatic C10-C12	300 µg/l	
TPH Aliphatic C12-C16	300 µg/l	
TPH Aromatic C5-C7	10 µg/l	
TPH Aromatic C7-C8	700 µg/l	
TPH Aromatic C8-C10	300 µg/l	
TPH Aromatic C10-C12	90 µg/l	
TPH Aromatic C12-C16	90 µg/l	
TPH Aromatic C16-C21	90 µg/l	
TPH Aromatic C21-C35	90 µg/l	

There are no available generic assessment criteria for some of the analytical parameters which have been scheduled, for example hexavalent chromium, and some VOC compounds. These parameters will be assessed based on professional judgement should they exceed the limit of detection.

RISK ESTIMATION - GROUND GAS

Introduction

A variety of potentially hazardous gases occur naturally in the ground environment. Microbial decay of organic matter under anaerobic conditions and geological processes can lead to the generation of Methane and Carbon Dioxide, but can also include trace gases such as Hydrogen sulphide and Carbon monoxide.

Methane is a colourless and odourless gas that has the hazardous properties of being flammable and, at certain air/Methane mixtures, explosive. Methane has a low toxicity, but can be a simple asphyxiant due to the displacement of oxygen.

Carbon Dioxide is a colourless, odourless and non-combustible gas that has the hazardous property of being a highly toxic chemical. At concentrations of 3% by volume, shortness of breath and headaches will occur becoming acute by 6%. At levels of above 10% by volume headache, visual distortion, tremors and rapid loss of consciousness occur. Concentrations of Carbon Dioxide above 22% by volume are likely to be fatal. The effects of Carbon Dioxide poisoning are made more severe if there is accompanying reduction in oxygen concentrations.

Hydrogen sulphide is a colourless and flammable gas that has an odour of rotten eggs. It is important that the sense of smell is overpowered at higher concentrations. The gas is toxic and can be an asphyxiant.

Carbon monoxide is a colourless, odourless and explosive gas in air mixtures that has the hazardous property of being a highly toxic chemical.

Radon is a naturally occurring colourless and odourless gas that is radioactive. It is formed by the radioactive decay of radium which in turn is derived from the radioactive decay of uranium, both of which are minerals that can be found in many soil types. Whilst it is recognised that the air inside every building contains radon, some buildings built in certain defined areas of the country might have unacceptably high concentrations and require special precautions to be taken. The maps contained within BRE211:2015 'Radon: guidance on protective measures for new buildings' identify areas where no radon protection measures are necessary or where higher concentrations are present that either basic or full radon protection measures are required to be fitted to all new buildings, extensions or refurbishments.

Basis of Gas Assessment

In order to classify the level of risk and need, if any, for gas protection measures at a site with the potential for a gas problem, consideration of each of the following is necessary:

- *The source of the gas.*
- *The generation potential of the gas.*
- *The location of the source and the geological setting.*
- *Boreholes flow rate and estimated surface emission rate.*
- *The nature of the proposed development.*
- *Confidence in the knowledge of the gas regime.*

The gas assessment is made with reference to 'C665 - Assessing risks posed by hazardous ground gases to buildings', Construction Industry Research and Information Association (CIRIA), 2007 and 'BS8485:2015 - Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings' BSI 2015.



Gas Screening Value

The methods within CIRIA C665 and BS8485 both use the gas concentrations together with the borehole flow rates to define a characteristic situation for a site based on the limiting borehole gas volume flow for Methane and Carbon Dioxide. This limiting borehole gas volume flow is called the Gas Screening Value (GSV) and is expressed below:

$$\text{Gas Screening Value (l /hr)} = \text{borehole flow rate (l/hr)} \times \text{gas concentration (fraction)}$$

The calculation of GSV is completed for both Methane and Carbon Dioxide and then the 'worse case' maximum values are used in the assessment. The assessment is to determine the gas regime at the site is dependent upon the nature of the development.

Characteristic Gas Situation

The characteristic situation for many sites is determined from evaluation of the Gas Screening Value derived against the criteria in the following table.

Characteristic situation	Hazard potential	Gas Screening Value (CH ₄ or CO ₂ l/hr)	Additional factors
CS1	Very low risk	<0.07	Typically Methane ≤1% and/or Carbon Dioxide ≤5%. Otherwise consider an increase to characteristic situation 2.
CS2	Low risk	0.07 to <0.7	Borehole air flow rate not to exceed 70 l/hr. Otherwise consider an increase to characteristic situation 3.
CS3	Moderate risk	0.7 to <3.5	-
CS4	Moderate to high risk	3.5 to <15	-
CS5	High risk	15 to <70	-
CS6	Very high risk	>70	-

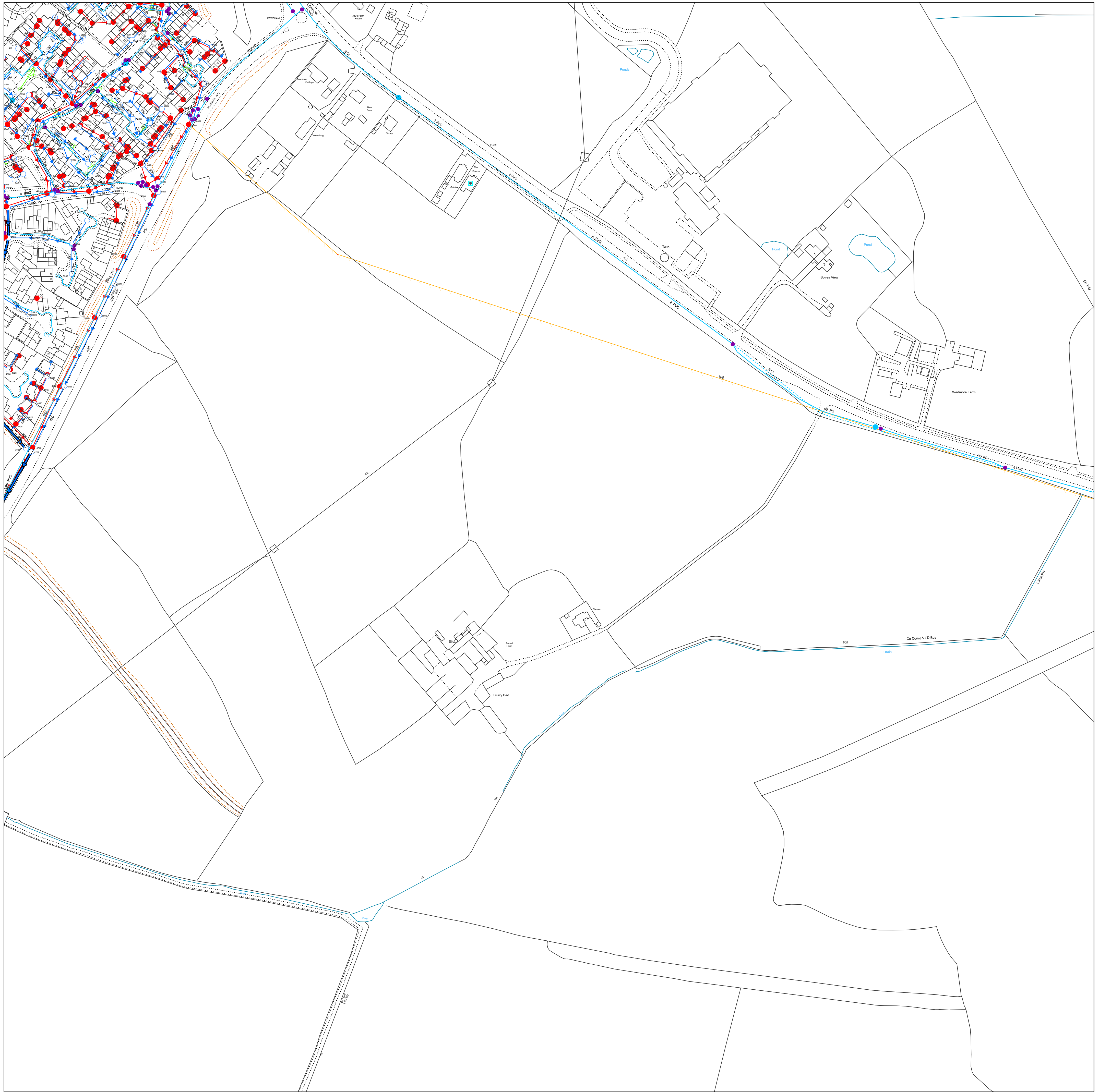
Low rise housing with gardens – NHBC 'Traffic Lights'

The NHBC model for low rise housing development considered a typical residential house with a ground floor area of 64m², suspended floor and ventilated sub-floor void of height 150mm. Where the proposed development of a site is consistent with this model, the NHBC traffic light situation of the site is determined from evaluation of the Gas Screening Value against the criteria in the following table.

Traffic Lights	Methane		Carbon Dioxide	
	Typical maximum concentrations (%)	Gas Screening Value (l/hr)	Typical maximum concentrations (%)	Gas Screening Value (l/hr)
Green	≤1	≤0.16	≤5	≤0.78
Amber 1	1 > to ≤5	>0.16 to ≤0.63	>5 to ≤10	>0.78 to ≤1.56
Amber 2	5 > to ≤20	>0.63 to ≤1.56	>10 to ≤30	>1.56 to ≤3.13
Red	>20	>1.56	>30	>3.13

APPENDIX E: Wessex Water Sewer Records

Wessex Water Web Map



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WATER MAINS		SEWERS		STATEGIC		PUBLIC		PRIVATE		SECTION 104		OTHER WESSEX PIPES		NON-WESSEX / UNKNOWN	
	Distribution		Foul										Rising Mains		Private Rising Mains
	Washout		Surface										Standby Rising Mains		Culverted Watercourse
	Raw Water		Combined										Effluent Disposal		Highway Drain
	Abandoned		Abandoned										Overflow		Use Unknown
	Private												Syphon		Status Unknown
Colours generally indicate the use of the sewer/drain (i.e Red - Foul, Dark Blue - Surface, Magenta - Combined/Dual Use, Light Green - Highway Drain, Mid Green - Overflow).															
Some styles of line and symbol are shown on the key in sample/typical colours.															
FITTINGS		STRUCTURES												OTHER STRUCTURES	
	Hydrant		Manhole - Foul		Pumping Station - Surface		Pumping Stn - Foul/Combined		Attenuation Tank		Tunnel		Interceptor		
	Other		Manhole - Surface		Gully		Vent Column		Storage Tank						
			Manhole - Combined		Flushing Chamber		Catchpit								
			Inlet		Outfall		Soakaway								
			Lamphole		Non Return Valve		Air Valve								
			Bifurcation - Foul		Non Return Valve		Air Valve								
			Bifurcation - Surface		Non Return Valve		Air Valve								
			Bifurcation - Combined		Non Return Valve		Air Valve								
			Combined Sewage Overflow		Non Return Valve		Air Valve								
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